UNITED STATES DEPARTMENT OF AGRICULTURE

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IRRIGATION REQUIREMENTS OF THE ARABLE LANDS OF THE GREAT BASIN

By

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Bureau of Public Roads

CONTENTS

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The problem of what constitutes an adequate water supply for irrigation of lands in the arid and semiarid regions is of vital importance to those regions. In an effort to solve this problem the Division of Agricultural Engineering, Bureau of Public Roads, of the United States Department of Agriculture, has been studying the duty of water for the past 25 years. A part of the results of the earlier experiments were published by State and Federal agencies, but the results of later cooperative experiments, as a rule, have not been published.

It now seems desirable to summarize and publish in bulletin form the data so collected. In order to treat the subject adequately, the arid and semiarid regions have been divided according to watersheds. This report relates to the Great Basin.

The Great Basin comprises an area of about 138,789,000 acres, of which 2,313,165 acres were irrigated in 1920. The crops grown include hay, grain, and potatoes at the higher altitudes, and alfalfa, grain, corn, fruit, and canning vegetables on the bulk of the arable lands at lower elevations.

It is estimated that eventually an area of 5,000,000 acres may be irrigated with the available water supply, or approximately double the area irrigated in 1920. This estimate is based on the assumption that water will be used much more economically than at present; that the supply will be regulated by means of storage reservoirs; and that waste or return water will be reused wherever possible. The seasonal net water requirement of crops under careful use is found to vary from 1.5 acre-feet per acre to 2.2 acre-feet per acre, depending on the locality.

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INTRODUCTION

The irrigation requirement of arable land, or, as it is frequently termed, the "duty of water" in irrigation, may be said to be the yardstick by which the utility of the diverted waters of western streams and the agricultural prosperity of the arid region are measured. This subject pervades irrigation in all its phases. It has to do with the legal phase in the definition and settlement of water rights; with the administrative phase in the equitable apportionment of public water supplies; with the engineering phase in determining the capacities of canals, pumps, reservoirs, and irrigation works in general; with the economic phase in the prevention of waste and the attainment of the highest possible efficiency; with the financial phase in determining the permissible cost of reclamation that can safely be undertaken with a known water supply, and with the agricultural phase in maintaining and controlling soil moisture in such a way as to produce profitable yields of crops.[1]

In most irrigated sections there was an abundance of water for irrigation for several decades after irrigation was begun. This

[1] Duty of Water in Irrigation, by Samuel Fortier. Proceedings of the International Engineering Congress, 1915, vol. 2, p. 458.

abundance of a natural resource led to lax methods in determining the rights of the users, and not infrequently excessive quantities of water were granted to individuals, associations, and corporations. These lax methods apply to a considerable part of the 19,000,000 acres irrigated in the United States in 1919, for which the water requirements were more or less arbitrarily fixed by various agencies. Due to the growing scarcity and increasing cost of public water, its apportionment in recent years has been made with increasing economy and equity, many former grants have been questioned, and many rights are being readjudicated.

A consideration of the unutilized water supplies and the economic benefits resulting from irrigation leads to the conclusion that fully 50,000,000 acres in the West may ultimately be irrigated. In other words, about 60 per cent of western water supplies are still to be utilized; but, judging from the trend of public sentiment in recent years, the apportionment of these supplies will be done with much more skill and economy than was exercised in alloting the 40 per cent now utilized. Furthermore, since fertile land is plentiful and cheap and water scarce and valuable, the ultimate prosperity of the Western States, from an agricultural point of view, will depend upon how wisely and equitably the water supplies are used. If too much water per acre is allotted, the ultimate possibilities of the land and water resources can not be attained. On the other hand, if too little water is allotted, profitable crops can not be raised and the interests of the farmer will suffer accordingly. To avoid either extreme and to place irrigation farming on a secure foundation, the quantity of water required to irrigate each kind of crop in each type of soil under the varying climatic conditions which prevail should be carefully determined. The results of such studies should be widely disseminated, in order to guide the correction of errors already made and make possible a more equitable and economical apportionment of all the available water supply.

Such an apportionment of water is rendered difficult by topography and other physical conditions. The higher mountain ranges intercept the moisture-laden winds and cause a relatively heavy precipitation of rain and snow. The locality of heaviest precipitation may, however, be quite far removed from the farms to be supplied with water, and the storage, conveyance, and distribution of the run-off involve heavy construction cost and require wise administrative regulations in order that the farmers may receive at the proper time an adequate supply of water. Wide fluctuations in stream flow, seepage losses from earthen channels, waste of water on irrigated lands, and the return and reuse of part of the waters diverted, all tend to complicate the undertaking.

Largely because of the scarcity of water and the injurious effects on soils and crops of using too much, several Western States have enacted laws limiting the quantity that can be used in irrigation. Some have created special tribunals and administrative bodies whose duty, in part, is to apportion the public waters within their respective jurisdictions. When litigation arises over water rights involving the duty of water for certain lands, it devolves on the judiciary to settle the controversies. In like manner, the management of irrigation enterprises, where the State does not interfere, de-

termines the proper amount of water to be delivered to their respective water users.

A study of the duty of water on western lands was begun by the Division of Agricultural Engineering,[2] Bureau of Public Roads, United States Department of Agriculture more than 25 years ago in an effort to solve the many-sided problem of what constitutes an adequate water supply for the irrigation of the standard crops and the modifications necessary on account of the prevailing types of soils and climatic conditions. Since then more or less experimentation along this line has been carried on by the department, chiefly in cooperation with western experiment stations. The results of the earlier experiments were published mostly in State and Federal bulletins which are now not easily procured. The results of later cooperative experiments, as a rule, have not been published.

The present is an opportune time to collect all the reliable records available pertaining to this subject and to publish the summarized data so collected. With this end in view the arid and semiarid regions have been divided into five subdivisions in accordance with river basins rather than political boundaries. The information in this report deals with the Great Basin.

UNITS AND FORMS OF EXPRESSION

Since irrigation was first practiced in this country various units and forms of expression have been used to indicate the quantity of water required to irrigate an acre or other unit of land. Those in most common use are defined below, with some of their equivalents.

The miner's inch represents, according to locality, the volume of water which will flow through an inch-square orifice under a constant head of 4 to 6 or more inches when measured from the surface of the water to the center of the opening. In southern California, Idaho, Kansas, New Mexico, North Dakota, South Dakota, Nebraska, and Utah 50 miner's inches equal 1 cubic foot per second; in Arizona, Nevada, Montana, Oregon, and central California, 40 miner's inches, and in Colorado 38.4 miner's inches have that equivalent.

An acre-foot of water is the quantity of water which will cover an acre to a uniform depth of 1 foot. It is equivalent to 43,560 cubic feet. An acre-inch is one-twelfth of an acre-foot.

Duty of water, as defined by Sir Hanbury Brown,[3] is "the measure of the efficient irrigation work that water can perform, expressed in terms establishing the relation between the area of crop brought to maturity and the quantity of water used in its irrigation." The duty of water is usually expressed in acre-feet per acre or in the number of acres irrigable by 1 cubic foot per second. Intake or gross duty is the average duty under a canal system when all transmission losses are included. Delivered or net duty is the duty at the margin of fields when all transmission losses are deducted.

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[2] The irrigation work of the United States Department of Agriculture was originally conducted under the supervision of the Office of Experiment Stations and designated as "Irrigation Investigations." Later, under a reorganization of the department, this and other agricultural engineering activities were grouped in a division of agricultural engineering and made a part of the Bureau of Public Roads.

[3] Irrigation, Its Principles and Practice, as a Branch of Engineering, by Sir Hanbury Brown, London, 1920, 3d edition, p. 32.

The soil moisture requirement of a crop is the amount of soil moisture expressed as a percentage of the dry weight of a unit of soil required for the proper growth of the crop.

The irrigation requirement of arable land is the amount of water, including the natural precipitation, required for profitable crop production under the physical and normal climatic conditions of the locality.

THE GREAT BASIN

The Great Basin (pl. 1), as Gilbert[4] has stated, "is not, as the title might suggest, a single cup-shaped depression gathering its waters at a common center, but a broad area of varied surface naturally divided into a large number of independent drainage districts." It includes within its confines about 95 per cent of the area of Nevada, all of western Utah, a long strip in California bordering on Nevada, and small portions of Oregon, Idaho, and Wyoming. It is 572 miles from east to west, 717 miles from north to south, exclusive of the Salton Sea Basin, which is now irrigated by the waters of the Colorado River, and contains in round numbers 138,789,000 acres. On the west the Sierra Nevada Mountains act as an enormous retaining wall in separating this territory from the central plain of California, and the Wasatch and Uintah ranges on the east serve a like purpose in separating it from the Colorado River drainage, and a divide at the north prevents its waters from joining those of the Columbia River. The divide between the Great Basin and that of the Colorado River, toward the south, is less clearly defined, as scant rainfall has prevented a deeply eroded ridge.

The aridity of its arable lands and the drainless character of its lakes and sinks distinguish this region from other parts of the country the streams of which drain either directly or indirectly into the ocean. Geologists are of the opinion that aridity has been the prevailing characteristic of the Great Basin for countless ages. It was only during a part of the Pleistocene period that semiarid conditions seem to have prevailed. At the time when the mastodon roamed over this high plateau the climate underwent a change. Due to an increase in precipitation, and possibly a decrease in evaporation, the run-off from the several watersheds exceeded the quantity of water evaporated and resulted in the natural storage of enormous quantities of it. Most of this excess water was stored in two lakes, one of which has been called Bonneville, in honor of the army captain and traveler of that name, and the other Lahontan, from another explorer of the region, Baron LaHontan. Lake Bonneville, of which Great Salt Lake is but a remnant, was 346 miles long, 145 miles wide, and had a surface area of 12,640,000 acres. Its highest shore line was about 1,000 feet above the present surface of Great Salt Lake, and when it was at this elevation that part of its annual inflow which was not evaporated was discharged into Snake River and later into the Pacific Ocean through the Columbia River. Lake Lahontan, on the other hand, was never filled. It reached an elevation about 525 feet above the present level of Pyramid Lake in western Nevada when the yearly loss from evaporation began to

[4] Lake Bonneville, Monograph No. 1, Geological Survey, U. S. Department of the Interior, by G. K. Gilbert, 1890.

exceed the inflow, and an intermittent lowering of the surface resulted. All that now remains of this great lake, which was 250 miles long, 180 miles wide, and covered an area of 5⅓ million acres, are a few relatively small, shallow lakes and several sinks. A large part of the area irrigated at present in both Utah and Nevada is located in the beds of these ancient lakes.

GENERAL CHARACTER OF THE SOILS OF THE GREAT BASIN

The soils of the Great Basin are probably more variable than those of any other large land division of the western part of the United States. The chief danger resulting from the irrigation of these soils is their tendency to become water-logged or alkaline.

Residual soils.—Weathering and decomposition of the rocks in place have led to the formation of a widespread variety of the soil material, confined mainly to the hills and mountains. These soils are often shallow and contain an excessive quantity of rock fragments or areas of rock outcrop, and, owing to rough topography and their elevated position with respect to sources of water supply, are generally nonirrigable. These conditions render most of the residual soils of the Great Basin suitable only for grazing.

The soils of the valleys and plains are of various origins and frequently have been transported long distances by wind or water or both. In many areas the soils have been laid under water. In some instances the lakes formed in past geological periods had two existences, with a dry-lake period between, resulting in a further complexity of the subsoils. The lake-formed benches have been cut through by streams and the valleys modified by fan-shaped deposits.

In the following paragraphs the valley soils have been grouped according to their formation. The adaptability of each type of soil to irrigation is briefly outlined.

Lake-laid soils.—These soils were formed under water and are for the most part rather dense, with poor drainage, and liable to contain an excess of alkali. They are usually deep, and while they may be rich in plant food are hard to handle under irrigation.

Alluvial fans.—These are the deposits of torrential streams and frequently cover lake-laid material. They are of irregular shape but of favorable topography and fairly smooth. The material varies from gravel and bowlders near the base of the mountains to loam or clay at the outer edge of the fan. The soils are of various depth, usually productive, well drained, fairly free from alkali, and are readily irrigated.

Valley fills.—These soils are also largely the result of stream action. They are mostly smooth, deep, and productive, but are deficient in drainage and liable to become alkaline. As a rule, they are near a water supply and easy to irrigate. They vary in texture for the most part from sands to clays. The valley fills, together with alluvial fans, form by far the greater part of the irrigable area of the Great Basin.

River flood plains.—These result from late river deposits or river erosion and deposition. Such soils are mostly well adapted to irrigation but liable to become water-logged and alkaline. The surface is usually level and smooth and requires little preparation for irrigation.

Volcanic soils.—These are derived from volcanic débris. They are very limited in the Great Basin and are confined principally to that part located in south-central Oregon. The soil is usually shallow but productive. The surface is irregular and difficult to irrigate. Most of these soils are basaltic.

CLIMATIC CONDITIONS

The prevailing climatic conditions of the Great Basin are low annual precipitation, abundant sunshine, low humidity, occasional high winds, a comparatively short crop-growing season, and comparatively low night and high day temperatures.

Climatological data have been collected from typical localities within the Basin where irrigation is practiced, and those pertaining to precipitation, temperature, frost-free period, evaporation from a water surface and wind movement have been averaged for the number of years of record at each station and are shown graphically in Figures 1, 2, and 3.

WATER SUPPLY

By far the larger part of the water supply of the streams in the Great Basin is derived from precipitation on the mountain ranges and elevated table-lands chiefly in the form of snow. The first warm weather of spring melts the snow at the lower elevations and as the season advances the run-off from higher elevations is increased. This continues until the latter part of May or the first week in June, when the run-off begins to decrease and continues to decrease until August 1 or later. During the late summer, fall, and winter months the streams remain low but fairly uniform in flow, barring the occurrence of storms. The prevailing characteristics of the flow of Basin streams are shown in Figure 4. These hydrographs, giving the mean monthly flow in acre-feet of each of three typical streams, show great differences between the volumes carried in the flood period and those of the late summer period. They also show the necessity for storing a part of the flood flow for use later in the same season to meet the water requirements of crops. For years the need for water storage has been keenly felt throughout the Great Basin. With few exceptions, the flood flow is unutilized and the only water available for crops during the latter part of the crop-growing season is derived from the scanty summer flow.

This condition has also induced many farmers to apply excessive quantities of water to their fields in the spring when the streams are high, in the belief that a part would be retained in the soil to nourish crops when little could be diverted from the streams. While this custom results in some benefits to those who practice it, from the standpoint of water conservation it has little to recommend it, inasmuch as the greater part of the excessive quantities of water applied in the spring percolates through porous soils, is diverted and reused, or collects in low-lying places, and damages soils and crops by water-logging and alkali.

A better and more economical plan is for each community of farmers receiving water from the same source or sources to unite into one organization such as an irrigation district, and, by the sale of bonds or otherwise, raise sufficient money to provide storage for a

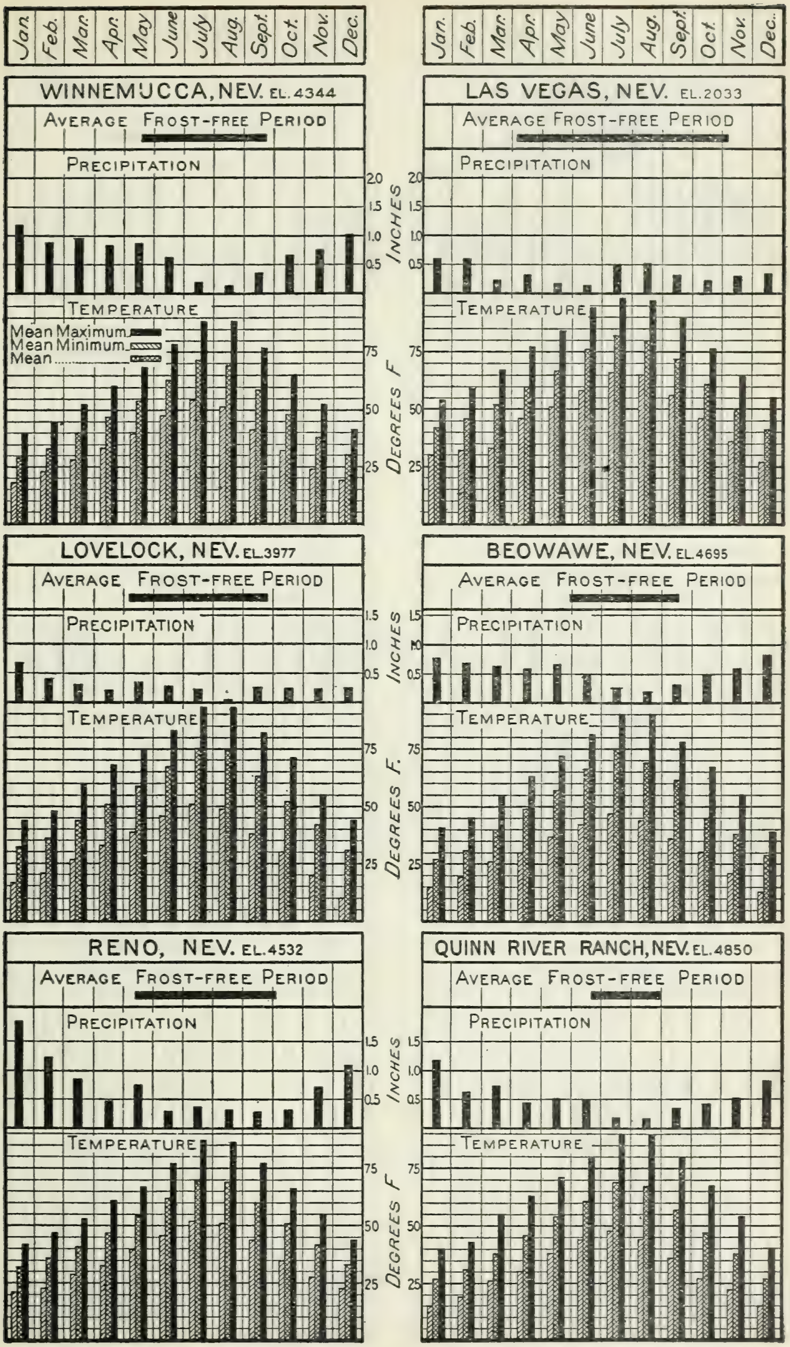

FIG. 1.—Condensed climatology of typical stations, showing average frost-free period; mean monthly precipitation and mean minimum temperatures (lightly shaded bars), mean temperatures (double shaded bars), and mean maximum temperatures (solid bars). While Las Vegas is outside Great Basin, the record is applicable to southeastern Nevada

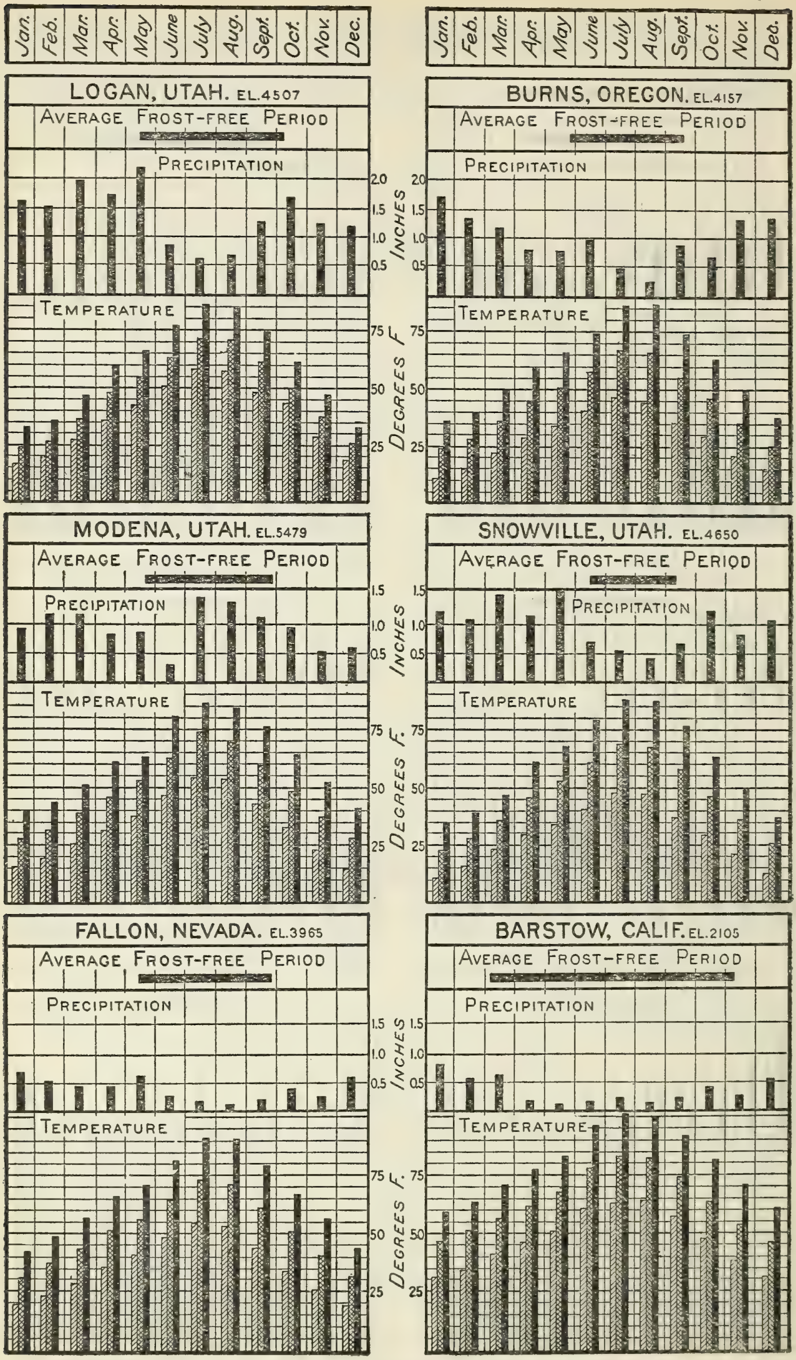

FIG. 2.—Condensed climatology of typical stations, continued; showing average frost-free period; mean monthly precipitation; and mean minimum (lightly shaded bars), mean (double shaded bars), and mean maximum (solid bars) temperatures

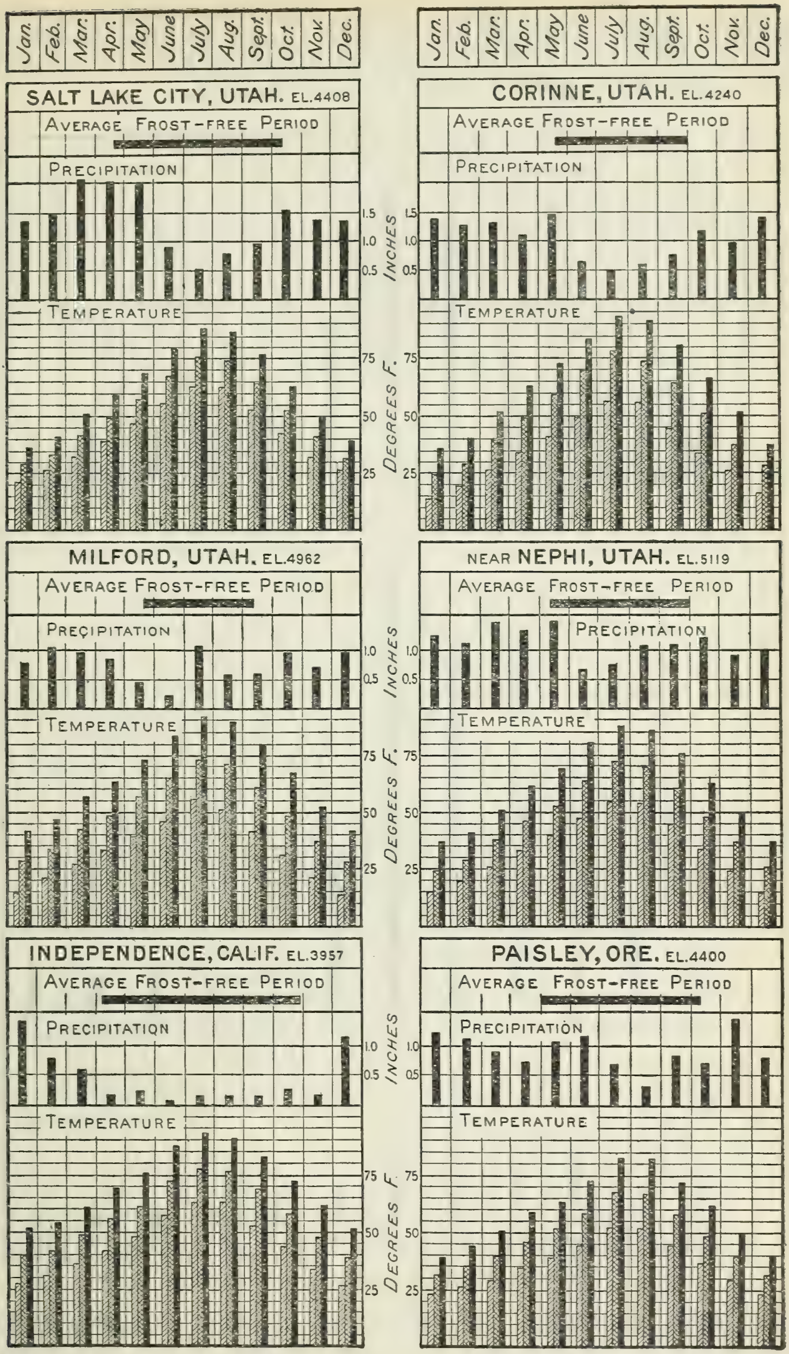

FIG. 3.—Condensed climatology of typical stations, continued; showing average frost-free period; mean monthly precipitation; and mean minimum temperatures (lightly shaded bars), mean temperatures (double shaded bars), and mean maximum temperatures (solid bars)

part or all of the flood flow and thus provide an adequate and dependable supply of water for all needs, from seedtime to harvest. With such storage facilities, there would be no necessity to apply more water at any one time than the crops require.

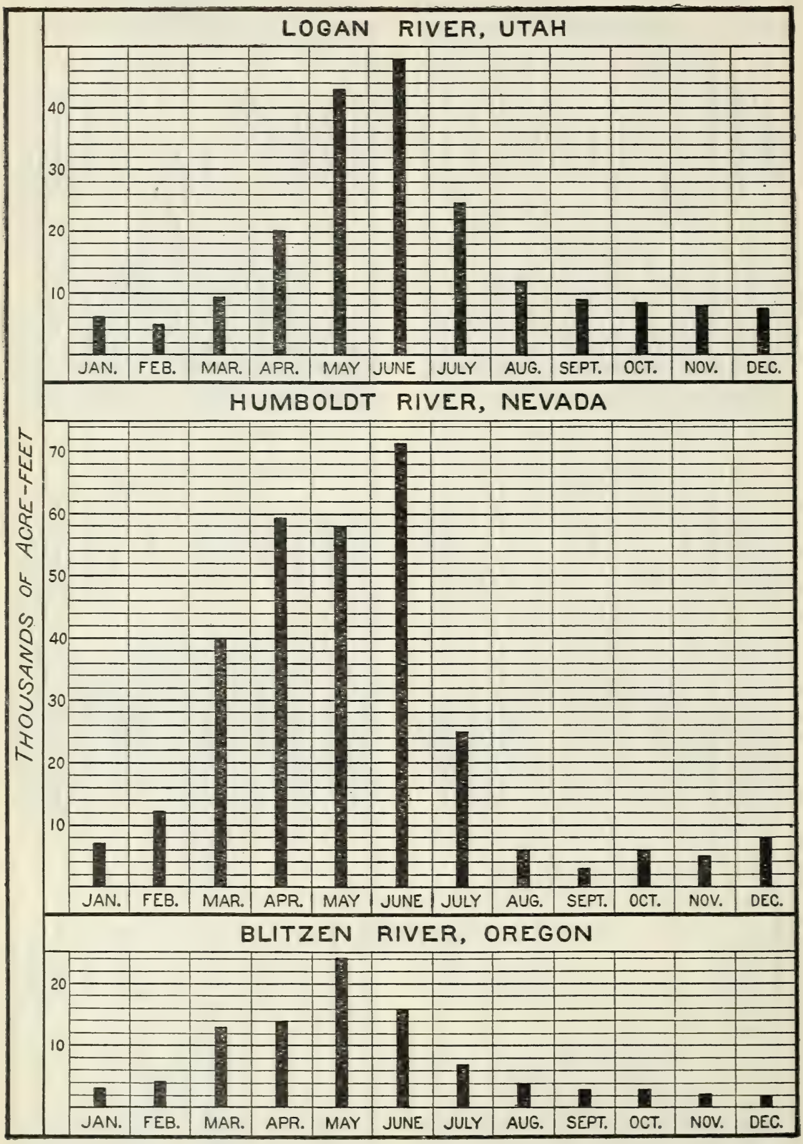

FIG. 4.—Mean monthly flow of typical rivers of the Great Basin

The storage of water, if carried out generally, serves a double purpose in that it provides water for irrigation and also develops hydroelectric energy. Part of the energy so created is used to pump water from underground supplies and from surface supplies too

low to be utilized by gravity. The potentialities of the Great Basin in this respect are very great, provided cheap electric power is available. As a result of surveys made in Nevada by the United States Geological Survey, a large area, in the aggregate, of the arable lands of that State has been found to be underlaid by ground water sufficiently near the surface to admit of being raised by pumps for agricultural purposes. Some nine years ago a creditable beginning was made by the Division of Agricultural Engineering, Bureau of Public Roads, in cooperation with the Utah Agricultural Experiment Station, landowners, and other local agencies, in determining some of the possibilities of ground water development in central and southern Utah by the installation of experimental wells and pumping plants. In this work special attention was given to the cost and most profitable use of pumped water. From 1914 to 1919, 14 pumping plants were installed in different parts of the State and assistance was rendered to a much larger number under the management of individual landowners. This cooperative work is still in progress and promises to add greatly to the productivity of the State.

The water supply of the Great Basin is further augmented by a large number of springs and creeks. Thus far these minor sources of supply have not been utilized to the best advantage, particularly the flow of the creeks whose sources frequently depend on melted snow at the higher elevations. Under natural conditions the flow in these creeks during low-water periods is absorbed, as a rule, by the coarse material of the foothills and fails to reach the arable lands. If such flows were conducted in pipes from the beginning of the porous material to the place of use, much of the water could be saved for useful purposes.

Since the extensive practice of irrigation was begun in the Great Basin, a large quantity of water has been derived during each irrigation season from seepage and return flows. As more economy is practiced in the conveyance and use of water, the amount of return water will diminish, but thus far it has greatly increased the available supply.

TABLE 1.—*Discharge of typical streams in the Great Basin*

River	Station	Years record	Water-shed area	Discharge for year		
				Maximum	Minimum	Mean
			Square miles	*Acre-feet*	*Acre-feet*	*Acre-feet*
Utah:						
Bear	Preston	24	4, 500	1, 648, 320	401, 000	1, 006, 620
Logan	Logan	25	218	370, 750	67, 000	245, 800
Weber	Devils Gate	10	1, 090	758, 000	180, 000	420, 000
Ogden	Ogden	9	550	479, 400	65, 300	228, 600
American Fork	American Fork	4	43	61, 690	7, 330	34, 470
Nevada:						
Humboldt	Palisade	7	5, 010	538, 000	86, 000	304, 000
Truckee	Reno	9	2, 370	1, 430, 000	305, 000	800, 000
California:						
West Walker	Coleville	49	405	1, 079, 000	110, 000	313, 800
Susan	Susanville	49	1, 507	1, 117, 000	80, 000	330, 800
Carson East Fork		49	323	868, 500	91, 300	309, 000
Owens	Round Valley	49	524	516, 000	181, 500	278, 100
Mojave	At Forks	49	211	407, 700	14, 200	98, 200
Oregon:						
Silver Creek	Silver Lake	8	317	48, 000	10, 000	32, 000
Donner und Blitzen	Diamond	2	500	134, 000	83, 000	102, 000

Some of the characteristics of the flow of typical streams of the Great Basin may be learned from a study of Table 1. The data in this table have been compiled from the reports of the Geological Survey and the Bureau of Reclamation, of the United States Department of the Interior, and State departments of engineering.

AGRICULTURAL PRODUCTS

Irrigation by the Anglo-Saxon race in this country was first practiced in the Great Basin. It was to ward off starvation that the early pioneers of Utah resorted to this method of raising crops. They soon found that in building ditches to convey water from mountain streams to cultivated farms, the individual possessed of small means could do little. It was, as a rule, only by cooperative effort that such a task could be performed. Thus at the earliest stage of agricultural development in the West, the spirit of independence so characteristic of the Anglo-Saxon farmer had to give place to one of community helpfulness and a willingness to join hands with others to accomplish a common purpose. Thus, too, the principle of cooperation so early established may be said to be the chief cornerstone of western irrigation. About 75 per cent of the irrigated area of the Great Basin of Utah is included in cooperative enterprises.

In that part of the basin lying in Nevada, California, and Oregon, the main agricultural industry is stock raising, and stockmen are as a rule financially able to construct their irrigation ditches. Accordingly, for the Basin as a whole, the largest area of irrigated land is under individual and partnership ditches. The next largest area is under cooperative enterprises, while irrigation districts occupy third place. With a few exceptions, the irrigation district is of recent origin in the Great Basin, but from present indications it bids fair to become an important agency in the remodeling of old and inferior irrigation systems. During the past decade 24 irrigation districts have been formed, of which 5 are being operated and an equal number are under construction.

Two projects of the Bureau of Reclamation, United States Department of the Interior, are located in the Great Basin, one being in Utah and the other in Nevada, but their combined irrigated area is less than 4 per cent of the total area irrigated in the Basin. With the exception of these two projects and some 30,000 acres irrigated by the Indian Service, United States Department of the Interior, irrigation development in the Great Basin may be said to be the result of private enterprise.

The increase in the irrigated area of the Great Basin during the decades beginning with 1890 is shown in the following figures:

Year	Irrigated area	Year	Irrigated area
	Acres		*Acres*
1890	703, 105	1910	2, 022, 277
1900	1, 451, 080	1920	2, 313, 165

The crops grown on the irrigated lands of the Great Basin include hay, grain, and potatoes in the more elevated and colder valleys, alfalfa, grain, corn, fruit, and canning vegetables on the bulk of the arable lands, and in the southern parts of both Nevada and Utah such crops as almonds, walnuts, and figs are successfully raised. The principal crops raised in Utah and the quantities of each produced during the census year in each decade since 1850 are given in Table 2.[5]

TABLE 2.—*Production of wheat, oats, corn, barley, potatoes, hay, and sugar beets in Utah during the census years from 1850 to 1920* [1]

Year	Wheat	Oats	Corn	Barley	Potatoes	Hay	Sugar beets
	Bushels	*Bushels*	*Bushels*	*Bushels*	*Bushels*	*Tons*	*Tons*
1850	107, 702	10, 900	9, 899	1, 799	43, 968	4, 805	
1860	384, 892	63, 211	90, 482	9, 976	141, 001	19, 235	
1870	558, 473	65, 650	95, 557	49, 117	323, 645	27, 305	
1880	1, 169, 199	418, 082	163, 342	217, 140	573, 595	92, 735	
1890	1, 515, 465	597, 947	84, 760	163, 328	519, 497	301, 901	
1900	3, 413, 470	1, 436, 225	250, 020	252, 140	1, 483, 570	850, 962	85, 914
1910	3, 943, 910	3, 221, 289	169, 688	891, 471	2, 409, 093	1, 015, 913	413, 946
1920	4, 100, 979	1, 724, 392	265, 361	365, 186	1, 648, 400	1, 031, 609	930, 427

[1] Formerly nearly 100 per cent and in 1920 about 67 per cent of these products were grown in the Great Basin.

According to the crop census report of 1919, the acreage devoted to various crops and the quantity of each produced in Nevada are given in Table 3.

TABLE 3.—*Acreage, yield, and value of principal crops grown on irrigated land in Nevada and comparisons with totals for the State, 1919*

Crop	Acres	Percentage of total for State	Quantity harvested	Value
Cereals:			*Bushels*	
Winter wheat	2, 921	83. 9	60, 220	$138, 506
Spring wheat	17, 062	92. 2	377, 248	867, 670
Oats	2, 501	84. 1	64, 873	74, 604
Barley	5, 156	92. 1	138, 793	242, 888
Hay and forage:			*Tons*	
Alfalfa	112, 166	95. 7	318, 906	6, 537, 573
Timothy alone	4, 229	94. 8	4, 855	111, 665
Timothy and clover mixed	14, 059	95. 8	19, 351	445, 073
Clover alone	487	62. 7	768	16, 896
Other tame grasses	29, 114	95. 3	31, 306	641, 773
Annual legumes cut for hay	706	91. 2	545	9, 810
Small grains cut for hay	5, 564	79. 0	6, 272	116, 032
Wild, salt, or prairie grasses	134, 389	75. 8	122, 146	2, 259, 701
Vegetables:			*Bushels*	
Potatoes	2, 823	77. 6	410, 001	918, 402

THE RELATION OF IRRIGATION WATER TO CROP PRODUCTION

The extent of arable land in the Basin is estimated as equal to that of Iowa, and the soil on the whole is rich in plant food and easily worked; but the rainfall is so light that the greater part is well-nigh worthless without irrigation, and dry farming is confined to a few favored localities where the precipitation is above the average and the soil is deep and retentive of moisture. The improved

[5] Circular No. 44, Utah Agricultural Experiment Station.

land in farms is confined to less than 3,000,000 acres, of which 2,313,165 acres were irrigated in 1919. It is from this relatively small area of irrigated land that the bulk of the soil products are derived. The large profits resulting from irrigation in the Basin as compared with those from nonirrigated land would seem to justify the expenditures which have been made in providing water supplies for agricultural purposes.

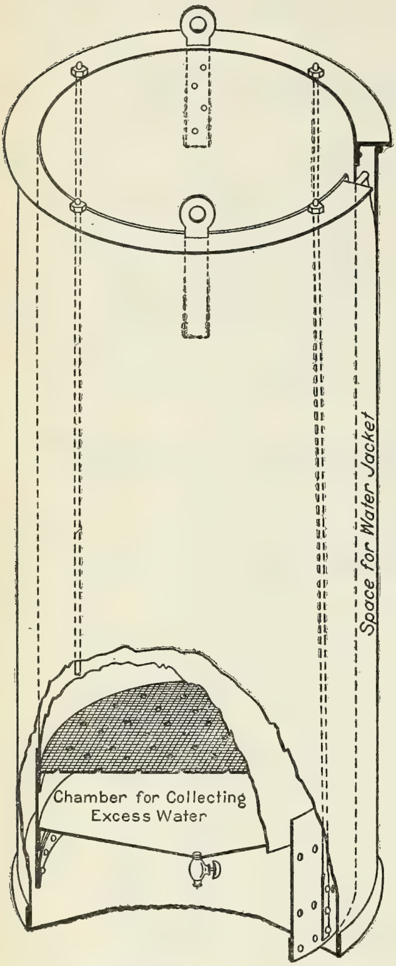

FIG. 5.—Double soil tank, showing inner shell with eyelets for hoisting and collar resting on edge of outer shell. Portion of tank shown as torn away to disclose screen resting on perforated plate, space for capture of deep percolation water and cock for withdrawal of this water

A large number of experiments have been made to determine the relationship between the amount of water applied to soil and the yield of crops. In all cases conditions were more or less under control, effected by growing crops under test in plots or in tanks.

In order to determine the actual water requirements of various crops during their period of growth, the Division of Agricultural Engineering has for years used metal containers known as tanks, in which the crops are grown and irrigated with varying amounts of water. These tanks are made of galvanized steel and vary in diameter from 18 to 30 inches and in depth from 4 to 6 feet. To facilitate weighing at short intervals and for the better control of temperatures, each tank is enclosed within a larger tank of similar design and the annular space is filled with water. In many cases the inner tank has a false bottom composed of brass gauze over No. 10 gauge plate and an outside tap through which water percolating through the soil column of the inner tank may be withdrawn and measured. The general design of the tanks is shown in Figure 5.

In 1901 a series of plot experiments was made on the Utah Agricultural Experiment Station Farm at Logan to determine, among other things, the effect of water on the yield of crops. The sandy soil, which varied in depth from less than 18 inches to 59 inches, was underlaid with gravel to a depth of several hundred feet. On account of the porous character of the shallow soil and the coarse, gravelly subsoil, more than the average quantities of water were used in order to compensate for deep per-

colation losses. The results, however, may be regarded as typical of those resulting from the use of water on the more porous bench lands of the Great Basin under the methods practiced 20 years ago.

Figure 6 shows the quantities of water applied to each of several plots of oats, wheat, potatoes, and corn, and the corresponding yields. To economize space the mean of the results of plots receiving nearly the same quantity of water has been inserted instead of those from each plot; the figures in the column headed "No. of Tests" give the number of plots or tests, which are included in each case.

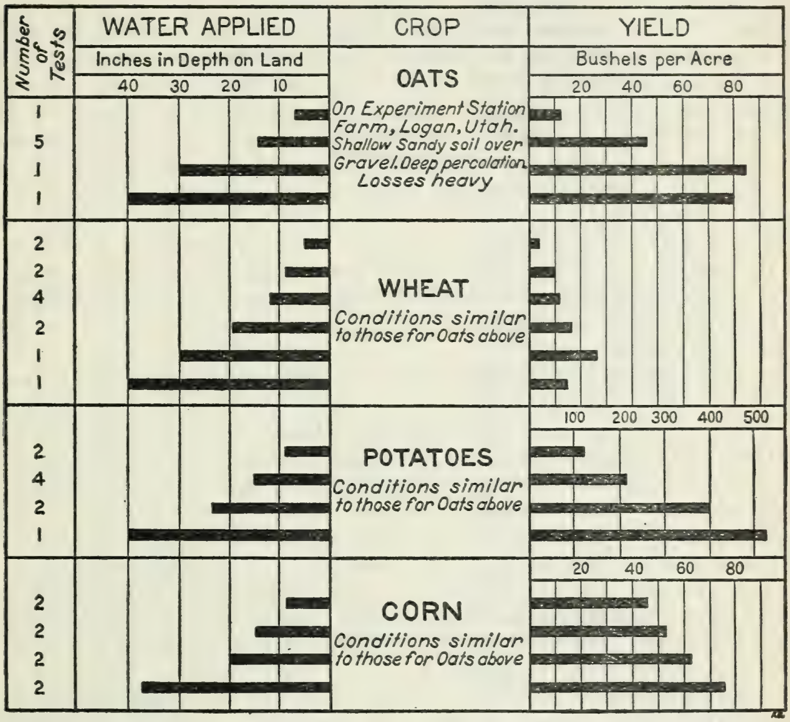

FIG. 6.—Relationship between amount of water applied and crop yield for oats, wheat, potatoes, and corn as determined by plot experiments at Logan, Utah, in 1901

Largely on account of the shallowness of the soil and the porosity of the gravel and cobble subsoil, the site of the experimental plots on which the foregoing results were obtained was abandoned at the close of the crop-growing season of 1901, and a new site was purchased about a mile and a half north of the Agricultural College of Utah, known as the Greenville farm. The soil of that portion of this farm devoted to irrigation experiments consists mainly of sand and silt and weighs, on an average, 76 pounds per cubic foot. The soil is comparatively uniform in texture, far removed from ground water, and of great depth. The maximum water-holding capacity under field conditions is about 24 per cent of the dry soil, the most favorable percentage of soil moisture for growing crops about 18

per cent, and the minimum percentage required for crop growth about 12 per cent.

From the close of the irrigation season of 1901 to January 1, 1911, irrigation experiments were conducted on the Greenville farm by the Utah Agricultural Experiment Station in cooperation with the Division of Agricultural Engineering, Bureau of Public Roads. A part of these investigations had for its object the determination of the relation existing between the quantity of water, including soil moisture and rainfall, used by various plants and the yields of these plants. This relationship is shown graphically in Figure 7, in which the mean of a large number of experiments on each of eight crops is given. During the 9-year period covered by these experiments the average annual rainfall at Logan, Utah, was about 17 inches. The early spring rainfall was heavy and the rainfall during the growing season was about 5 inches. This rainfall, which is far above the average of the Great Basin, coupled with the fertility of the soil and the quantity of soil moisture available, was sufficient to produce, as the diagram shows, fairly good yields when small quantities of irrigation water were added. To illustrate, an equivalent of 10.25 acre-inches of soil water and rainfall, with the addition of 5 acre-inches of irrigation water, produced 6,080 pounds of dry matter per acre, composed of the roots and tops of sugar beets, whereas the addition of 30 acre-inches of irrigation water produced 10,271 pounds of dry matter per acre.

In 1905 a series of experiments was carried on in several counties of Utah by the Division of Agricultural Engineering, Bureau of Public Roads, in cooperation with the Utah Agricultural Experiment Station to determine among other facts the effect on yields of variations in the quantity of water applied, above a relatively small amount. The results are shown graphically in Figure 8. The alfalfa was grown at Richfield, Utah, on a soil composed chiefly of clay and sand. The oat crop was grown on clay-loam soil near the town of Tooele in Tooele County. The sugar beets were grown on sandy, gravelly loam underlaid with coarse gravel, near Provo, Utah County. The potatoes were grown on a black loam soil mixed with clay in Salt Lake County.

Cooperative irrigation experiments on a 40-acre tract near Gooding, Idaho, were begun in 1909 and continued to the close of 1916, by the Division of Agricultural Engineering and the Idaho Agricultural Experiment Station. The soil of the tract is a medium clay loam with a clay subsoil underlaid at a depth of 8 to 12 feet by the basaltic lava rock common to southern Idaho. The precipitation during the crop-growing season (April 1 to August 31) for the years 1910 to 1916 inclusive, averaged 2.91 inches and the temperature for the same 7-year period ranged from a monthly minimum of 8.3° F. to a monthly maximum of 95.9°, while the average yearly mean was 47.2°.

The tract on which these experiments were made lies outside the Great Basin, but the soil and climate conditions are similar to those of the southeastern part of Idaho located within the Great Basin.

In determining the quantity of irrigation water necessary to produce profitable yields, one set of plots received a small quantity of water, another set a medium quantity, and a third set a larger

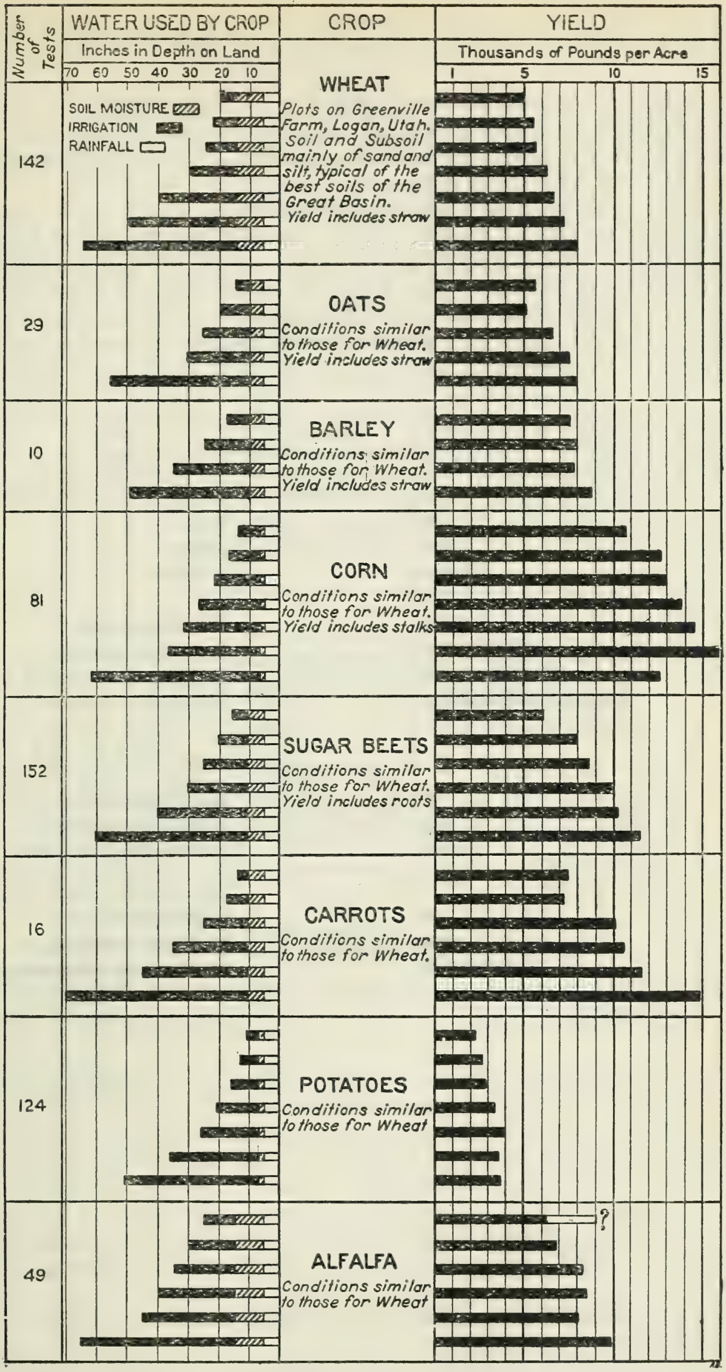

FIG. 7.—Relationship between amount of water applied and yield for various crops as determined near Logan, Utah, between 1901 and 1911

quantity. The water used was measured over a weir and all run-off was measured and deducted from the quantity passing over the weir.

The relation between the total quantity of water applied exclusive of the rainfall and the yields of alfalfa, spring wheat, oats, and potatoes is shown graphically in Figure 9, in which the average of a large number of tests is given.

On April 25, 1911, 6 tanks each containing about 1,000 pounds of soil, were seeded to alfalfa at the Nevada Agricultural Experiment Station. This experiment formed part of the cooperative irrigation investigations carried on for a number of years by the Bureau of Public Roads and the Nevada Agricultural Experiment Station. The soil used was alluvial in character, intermixed with a considerable proportion of sand and small rock fragments, and typi-

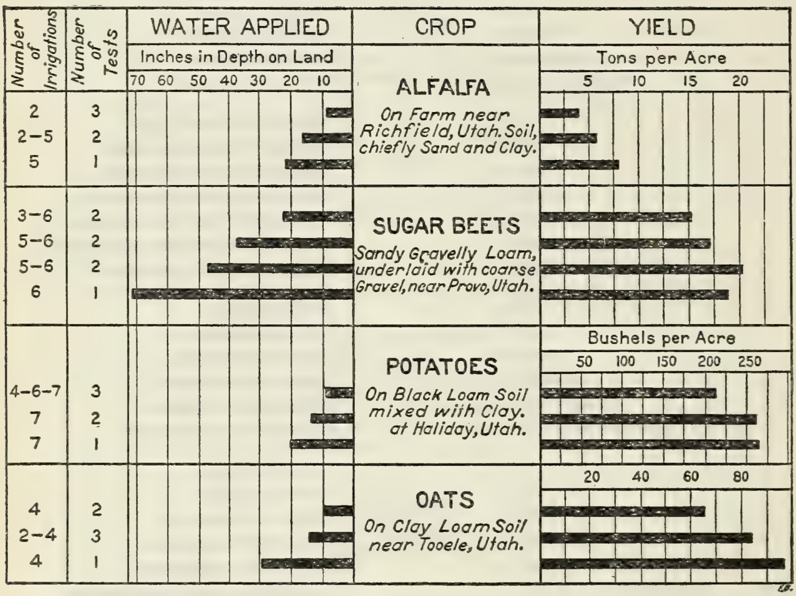

FIG. 8.—Relationship between amount of water applied and crop yield for alfalfa, sugar beets, potatoes, and oats as determined at various places in Utah in 1905

cal of soil formations in the vicinity of Reno. Soil samples taken when the tanks were filled had moisture percentages of 11.9 to 12.8.

Tanks 3 and 4 received 4 light irrigations during the season, in which 3 crops were harvested; tanks 5 and 6, received 4 medium irrigations; while the soil in tanks 7 and 8 was maintained at a fairly constant moisture content by adding, at the time of the semi-weekly weighing, the quantity of water lost by transpiration and evaporation. This plan was believed best to insure vigorous plant growth.

The experiment was continued through the season of 1912, with the results as shown in Figure 10.

On April 23, 1913, the tanks used in growing alfalfa the two previous years were seeded to Marquis wheat. As in the case of alfalfa, tanks 3 and 4 received relatively small quantities of water, tanks 5

and 6 medium quantities, while the soil in tanks 7 and 8 was maintained at a fairly constant moisture condition. Similar experiments were made by growing oats in tanks.

The mean quantity of water utilized in each set of tanks in growing wheat and oats and the corresponding seasonal yield are shown in Figure 10.

TIME OF IRRIGATION

The purpose of this discussion is to indicate as definitely as the varied conditions will permit, the quantity of water needed by typical crops during their successive stages of growth, in order to

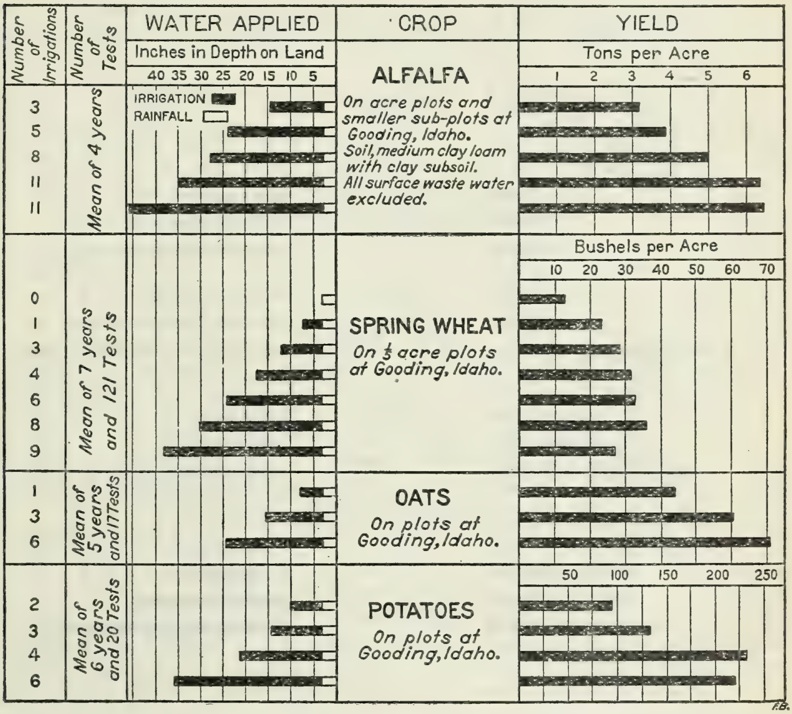

FIG. 9.—Relationship between amount of water applied and crop yield for alfalfa, wheat, oats, and potatoes, as determined by plot experiments at Gooding, Idaho, from 1909 to 1916. While Gooding is outside Great Basin the results are applicable

serve as a guide to irrigators in deciding when water should be applied.

If it were practical to maintain in each type of soil the quantity of soil moisture best adapted to the kind of crop grown, it would go far toward settling the question of proper time of water application. Of the many ways of applying water to soils and crops, the sprinkling method [6] may be considered the only one by which small quantities of water can be spread uniformly over the soil at frequent intervals in order to maintain a reasonably constant soil moisture content.

[6] U. S. Department of Agriculture Bulletin No. 495, Spray Irrigation.

This method, however, is costly and not well suited to arid conditions. Ordinarily crops grown in the West are irrigated with large quantities of water at certain periods and when these periods are limited to two or three in the growing season, it is not easy to determine in all cases the proper time to use water.

While it is generally true that the more foliage a plant has the more water it transpires and the greater is its need for soil moisture, cases arise like that of a newly cut alfalfa field where the transpiration is small, yet the need for water is urgent in order to start the new growth.

When the growth of plants is checked—especially at a time when it is most rapid—by a lack of moisture, complete recovery is not possible, and a smaller yield, depending upon the severity of the check, is the result. To guard against such an occurrence, an adequate amount of soil moisture should be maintained during the critical stages of growth, because when crops suffer a setback on account of drought no subsequent waterings will repair the damage done. It is also true that the application of water to many crops approaching maturity results in injury rather than benefit.

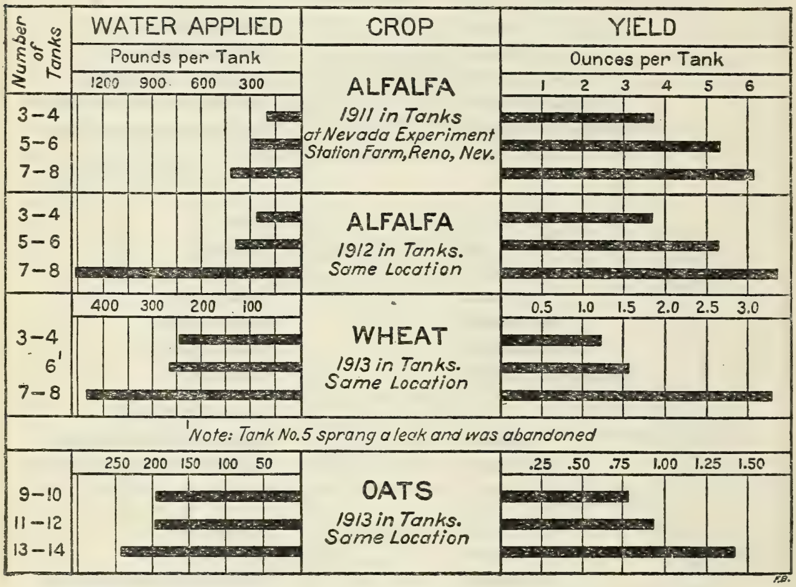

FIG. 10.—Relationship between amount of water applied and crop yield for alfalfa, wheat, and oats as determined by tank experiments at Reno, Nev.

Before taking up the question of the proper time to apply water to typical crops, it will be necessary to consider briefly the influence which several secondary factors exert in causing more or less departure from theoretical conclusions based solely upon the water requirements of the crops under consideration.

Of the secondary factors, the character of the soil is one of the most important. Some soils when irrigated retain little water, necessitating frequent light waterings in order to supply enough soil moisture for the use of crops. Sandy and gravelly soils having

relatively large particles belong to this type. Other soils are made up largely of small particles and are in consequence retentive of moisture and do not permit much water to percolate through them. Silt and clay soils are of this type and these as a rule do not require water as frequently as the more porous soils.

Cropped soils having a water table near the base of the root zone need little, if any, water applied to the surface of the soil, since moisture is drawn from beneath.

The time of irrigation is also influenced by precipitation. In some parts of the West enough moisture is stored in the soil, resulting from rainfall or the melting of snow, to nourish plants during their first stage of growth. Under such conditions no artificial watering is needed until the roots of the growing plants threaten to deplete the soil moisture below the desired amount. In other parts of the West most of the precipitation occurs during the winter season and irrigation is needed shortly after crops are planted if not before.

There is likewise a wide seasonal fluctuation in the flow of Western streams. To lessen the injurious effects of the lack of water during the late summer months, a common practice is to apply surplus quantities when there is an abundance, and this is done with little regard to the need of the crops for water at the time of application. While this practice increases the yields, it is wasteful of water and tends to water-log fertile land. As stated elsewhere, the better practice is to store a part of the surplus flow and to apply water from stream and reservoir as the soil and crops require it. This more economical method is being followed wherever funds are available to build works for the storage of water.

The regulations in vogue governing the delivery of water to those entitled to its use exert a marked influence on the time of irrigation. For the most part water is delivered to water users in rotation. In other words, all the farms furnished water from a lateral ditch receive the entire stream in turn and the number of hours of use is apportioned to each farm in accordance with the number of acres watered. On small farms, the number of hours of use may be less than 24, while the period between water deliveries may vary from less than 10 days to more than 30 days. Under such regulations in respect to water delivery, it is not always possible to irrigate crops at the proper time.

Lastly, the varied and at times pressing duties of operating an irrigated farm often render it inadvisable to quit an urgent task in order to irrigate. In the Great Basin the harvesting of alfalfa often occurs at a time when sugar beets or other crops need irrigating. The delay in irrigating a particular crop by first harvesting the alfalfa may affect the yield of that crop. On the other hand, the delay in harvesting the alfalfa when ready to cut, may incur as great a loss.

THE CEREALS

The amount of soil moisture absorbed by the roots of plants and transpired through the foliage varies quite widely in most crops in accordance with the condition of the plant and the stage of growth. In the case of cereals, for example, a relatively small quantity of soil moisture is absorbed and transpired from the time of

germination until the plants are well above the ground. From that stage to the heading-out stage, there is a gradual increase in water requirements and a more rapid increase beyond this latter stage up to the time of the beginning of the milk stage of the grain. Beyond the hard-dough stage there is a sudden decrease in the quantity of soil moisture needed and this lessening requirement for moisture continues until the grain is harvested.

This is shown in diagrams "A" and "B" of Figure 11, which represents the results of tank experiments by Fortier and Petersen at the Nevada Agricultural Experiment Station farm near Reno in the summer of 1914. Diagram "A" represents the mean of six experiments in which Marquis wheat was grown in tanks.

In "A" the stepped line shows the quantity of water used at the various stages of growth. Every three or four days water was added to each tank to replace that used in transpiration and evaporation from the soil surface. Accordingly each horizontal step represents the average quantity of water used by all the tanks during the period covered since water was last added. As nearly as could be determined, the ratio of the loss due to evaporation and transpiration was as 1 is to 2.44. Each tank on an average received 359 pounds of water and about 71 per cent of the total was due to transpiration. The tanks were fitted with false bottoms so that all deep percolation water was withdrawn through a tap and the quantity deducted from that applied to each tank. Soil moisture determinations were also made at seed time and harvest time and the gain or loss of soil moisture included in the final results. In like manner due allowance was made for rainfall.

Diagram "B" represents the mean of five tank experiments for the purpose of determining the water requirements of barley at various stages of growth. These experiments were conducted simultaneously with those represented by Diagram "A" and the meteorological data are the same for both.

The Utah Agricultural Experiment Station has demonstrated repeatedly (1) that if cereals can be watered but once in their period of growth, this one irrigation should be applied about the time of the early booting stage so as to supply ample moisture for the plant stage requiring most water; (2) that water applied after the dough stage is reached decreases the yield and tends to lodge the grain, and (3) that the largest yields are obtained by maintaining an adequate moisture supply in the soil by the necessary number of irrigations until the soft-dough stage of the cereals is reached. The graphical representations of Figure 11 seem to give a reason for these demonstrated facts.

Thom and Holtz, in growing plants in tanks under irrigation at Pullman, Wash., during the seasons of 1911 and 1912, found that the daily quantity of water transpired by wheat, corn, oats, and peas increased until about the beginning of the ripening period and then decreased until harvested. The daily quantity of water transpired by each of these plants, expressed in pounds, is shown in Figure 12. The same authors found that in growing wheat, corn, oats, and peas on plots adjacent to similar control plots which were uncropped, the averaged ratio of the quantity of water transpired to that evaporated from bare soils was approximately as 3 is to 1. The rainfall

during the growing season averaged 3.3 inches for the wheat, oats, and peas, and 3.15 for the corn.

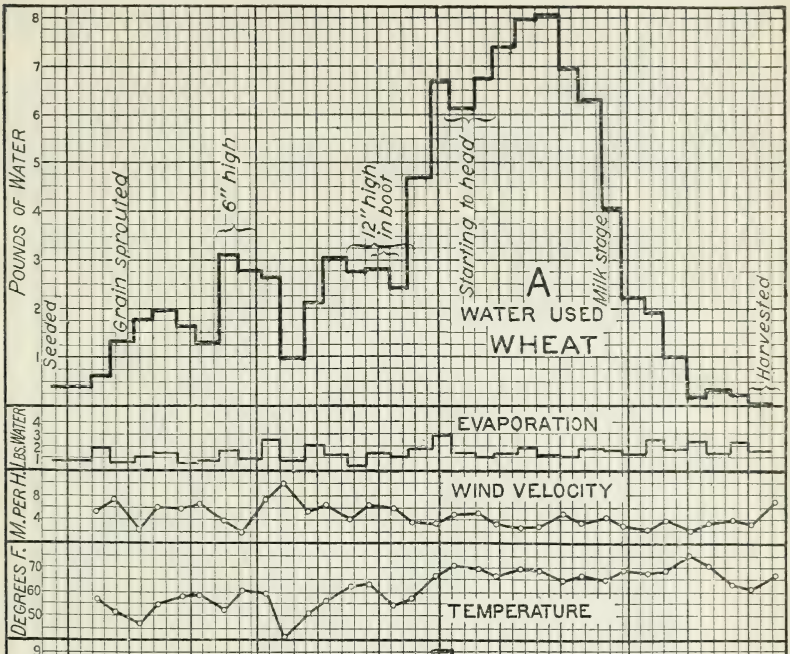

FIG. 11.—Water requirements of (A) wheat and (B) barley at various stages of growth as determined at Reno, Nev., in 1914. Modifying meteorology also given. The lines represent mean values for several days

The water requirements of cereals during the several stages of growth as determined by tank experiments agree closely with those of similar crops grown in plots near Twin Falls, and near Gooding, Idaho. The results of experiments carried on for three seasons at

the former station showed that there should be enough moisture in the soil at the time of planting to sprout the seed and maintain the crop in a vigorous condition to the beginning of the jointing stage. By plowing the ground in the fall, leaving it rough during the winter and cultivating and seeding early in the spring, there is usually enough moisture in the soil in that locality to meet this requirement. If, however, the ground is not plowed in the fall, the season late or dry, a medium irrigation may be necessary before planting. The results also showed that the greatest need for water occurred between the jointing and the soft-dough stages. A heavy irrigation about the time of early jointing produced a large head and supplied

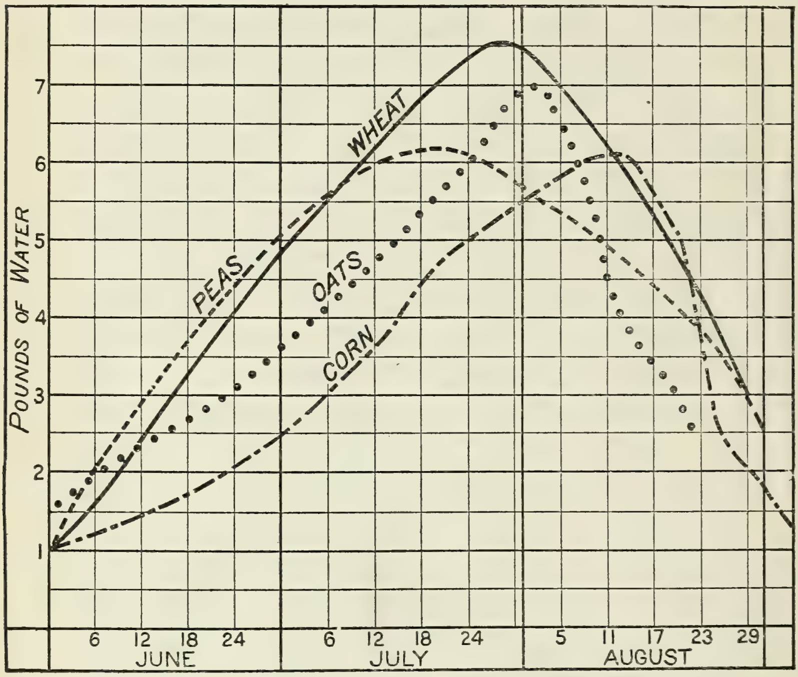

FIG. 12.—Water used during various stages of growth as determined at Pullman, Wash., in 1911 and 1912. Average of 4 tanks, each of 3-1/7 sq. ft. area

sufficient moisture for subsequent growth. When water was withheld during this period and applied after the soft-dough stage, the effect was injurious rather than beneficial. The best yields were obtained by maintaining a fairly constant soil moisture content from the time of seeding until the hard-dough stage was reached.

The results obtained in growing cereals at the substation of the Idaho Agricultural Experiment Station at Gooding likewise showed the advantage in crop yields of an adequate supply of moisture until the hard-dough stage was reached. When the crop was not irrigated during its critical stages of growth, the quantity of the yield was reduced and its quality impaired. No subsequent waterings could remedy the damage done. In many cases the application of water three weeks or less before harvest time tended to lodge the grain

and otherwise worked an injury. References to results obtained at Pullman, Wash., Gooding and Twin Falls, Idaho, although located outside the Great Basin, are introduced for the purpose of comparison with those obtained in the Great Basin and because conditions are somewhat similar.

FORAGE CROPS

Alfalfa, clover, and other forage crops differ in certain features from the cereals in their water requirements during their several stages of growth. As with the cereals, the need for water is small in the case of newly seeded alfalfa during the first stage of growth.

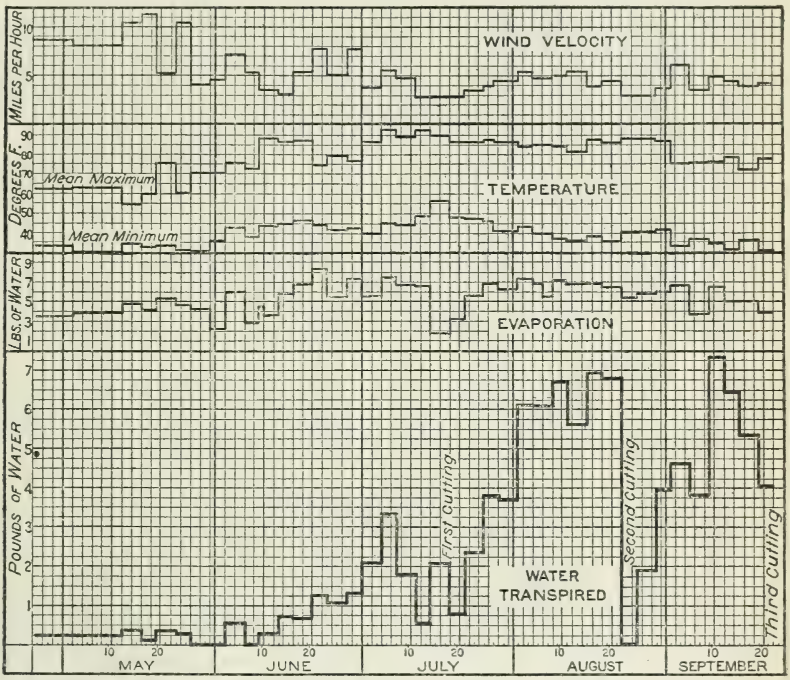

FIG. 13.—Amount of water transpired during growth prior to each of three cuttings of alfalfa, as determined at Reno, Nev., in 1911. Modifying meteorology also given. The stepped lines represent mean values for several days

The demand for water increases, however, quite rapidly as the foliage expands, and this increase is accelerated until the root system is well established and the aerial part of the plant approaches full development. From this stage to the time of harvesting, the increase in water requirement is fairly constant, provided the alfalfa is cut in early bloom. If the cutting is deferred to late bloom or beyond, there is a falling off in the amount of water needed. Figure 13 is a graphical representation of the quantity of water transpired daily by alfalfa grown in tanks at Reno, Nev., in 1911. It will be noted that it required from April 25 to July 18 (84 days) to mature the first crop and during this period the transpiration was low and the growth slow. The next crop matured in 35 days and required during

the last half of this time a large quantity of water. The third and last crop of the season matured in less than 30 days and required somewhat less water than the second crop. The results shown are the mean of four experiments. The quantity of water evaporated from a water surface during the growing of the three crops, the wind velocity, and the temperature are also shown.

POTATOES

An essential feature in the production of large yields of marketable potatoes is to maintain as constant a soil moisture content as conditions will permit. A medium amount of soil moisture is to be preferred to either a high or low one. If the soil is too dry at the time of planting, it should first be irrigated in order to furnish the plants with sufficient moisture until the vines are 4 to 6 inches high. From this stage until the potatoes are nearly mature the ideal procedure would be to apply a small quantity of water each week. The nearest approach to this which is practical in the Great Basin is to apply about four light irrigations. If the soil is moist at the time of planting, the first of these may be given when the vines are 4 to 6 inches high, the second when tubers begin to form, the third when the vines are in bloom, and the fourth prior to ripening.

In experimenting with the irrigation of potatoes at the Nevada Agricultural Experiment Station during the years 1914 to 1917, inclusive, the plan adopted was to apply water when the vines showed a tendency to wilt. The depth of water applied at each watering was 3 inches for one series of plots, 6 inches for another, and 9 inches for the third series. For the 4-year period, the highest yields were obtained with 3-inch applications given when the vines started to wilt.

As a result of years of experimentation with potatoes at the Utah Agricultural Experiment Station, the highest yields have been obtained by 1-inch applications weekly for a period of 13 weeks. Since such light applications are seldom practical under field conditions, this station has adopted, with good results, the practice of applying fairly frequent light irrigations extending from the time the vines are 4 inches high until the plants are nearly ripe. Other phases of this subject brought out by the Utah experiments are that the yields of potatoes are decreased by too much water and by irrigating after planting and before the plants are above ground, that if only one irrigation can be applied during the period of growth, it should be at the time of full bloom, and that if the soil is allowed to dry out to such an extent as to check growth, knobby or gnarled tubers may result from a subsequent watering.

SUGAR BEETS

It was formerly quite generally held that water should be withheld from sugar beets as long as possible during their first stage of growth in order to produce long roots. Observations and the results of experimentation during the past decade have shown that this practice is not profitable. Depriving young beets of water may induce deep rooting but this slight advantage is apt to be counterbalanced tenfold by the injury done to the plants in thus checking

their growth. Good practice seems to call for a thorough preparation of the seed bed by deep fall plowing, followed by cultivation in the spring and an adequate supply of soil moisture. If the moisture supply is not sufficient under natural conditions, the field should be irrigated some time before seeding. When the top layer of soil is carefully prepared after water has been applied, and contains the right quantity of moisture, the beet plants should germinate promptly and make a rapid growth. Beets grown under favorable conditions should possess normal shapes. The deformities arise, as a rule, from drought, hardpan, a high water table, alkali, or disease.

The maintenance of a soil moisture content as nearly uniform as practicable is a reliable guide in determining when sugar beets should be irrigated. This rule holds true to within a short time of maturity. The additional profits to be gained in irrigating whenever the plants are in need of water was demonstrated by the Great Western Sugar Co., at their experiment farm at Longmont, Colo. In this experiment one set of plots, No. 1, was irrigated June 27, July 22, and August 12. This set was termed "early irrigated"; set No. 2, irrigated July 22 and August 12, was termed "intermediate"; set No. 3, irrigated August 12 and September 18, was termed "late," and set No. 4, irrigated June 27, July 22, August 12, August 24, and September 6, was termed "when in need of irrigation." The yield, sugar content, and farmers' profits for each set are given below.

Number of set	Yield per acre	Sugar content	Farmers' profit
	Tons	*Per cent*	
1	16.89	14.79	$82.53
2	16.57	14.95	79.63
3	15.69	13.93	75.97
4	18.87	15.25	93.66

The proper time to irrigate sugar beets was investigated by the Nevada Agricultural Experiment Station in 1914 and 1915 on 19 plots.

A 4-inch irrigation was applied at each of four stages of wilting with the following results:

Stage	Yield per acre	Sugar content
	Tons	*Per cent*
Before plants began to wilt	11.31	20.92
When plants began to wilt	9.67	21.48
When the leaves wilted down once	9.40	21.01
When the plants failed to revive at night	7.38	18.59

During the growing season of 1919 sugar beets were grown in tanks 23½ inches in diameter and 48 inches deep, at the Denver field laboratory in Denver, Colo., by Fortier and Blaney. Figure 14 indicates graphically the quantity of water in pounds which was

transpired by the sugar beets during their period of growth, as determined by the mean results of three tank experiments. The moisture content in each tank was maintained as nearly as practicable at 17 per cent of the dry weight of soil, by adding water at each semiweekly weighing to make up the loss due to transpiration and evaporation. The loss due to evaporation from the soil in each tank was afterwards deducted. The mean temperature of the air, evapo-

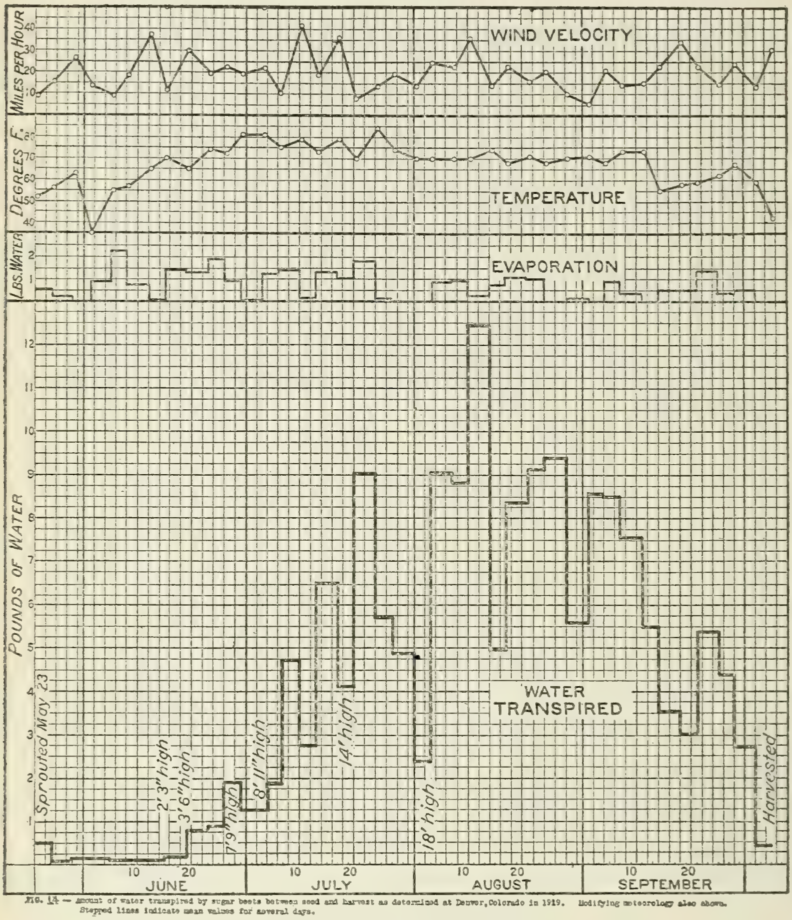

FIG. 14.—Amount of water transpired by sugar beets between seed and harvest as determined at Denver, Colo., in 1919. Modifying meteorology also shown. Stepped lines indicate mean values for several days

ration from a water surface, and wind movement during the period of growth are also given.

It will be noted that the quantity of water transpired is small from the time the sugar beets are sprouted on May 23 until they are 4½ inches high on June 20. From this stage the transpiration increases quite rapidly and uniformly until August 4, when the beets are 18 inches high. From the middle of August until October 7,

when the crop is harvested, there is a gradual decrease in transpiration from 12 pounds to less than 1 pound per day.

As has been pointed out, conditions imposed on the farmer may prevent him from irrigating at the right time and with the proper quantity of water. When possible, however, water should be supplied as needed during the various stages of growth of the crops. To do this, there should be an adequate and dependable supply of water throughout the irrigation season.

CONDITIONS INFLUENCING THE QUANTITY OF WATER REQUIRED FOR IRRIGATION

Of the conditions influencing the quantity of water required for irrigation in the Great Basin, what may be termed permissible waste of water is by far the most important. As shown by many of the records of duty-of-water measurements herein tabulated, much larger quantities of water are diverted from streams and other sources of supply than can be utilized by the crops irrigated. The difference between intake duty and the actual water requirement of crops is made up of losses in the conveyance of water from the source to the place of use, unequal distribution over the surface of fields, the application of more water than soils can hold, causing deep percolation losses, surface run-off, and other more readily preventable losses. It is estimated that fully half of the water annually diverted for irrigation purposes within the Great Basin is thus wasted. Bark's estimate for southern Idaho, where irrigation conditions are somewhat similar, was 55 per cent loss exclusive of evaporation from soils.

In order to ascertain the percentage of this waste water which may be conserved economically, it is necessary to determine the relation between such factors as the value of water and the cost of conserving it, the value of crops and the profits derived from them, and also the damage inflicted by waste water, but as these are all variables, it is not possible to reach any definite conclusion. It may be stated, however, that the general trend is toward a more economical use of water, largely on account of the growing scarcity of water and its rapidly increasing value, as well as the increasing damage due to water-logging and the cost of drainage. To illustrate: In 1898 a water right under the Bear River canal system in northern Utah was worth $10 per acre; 25 years later the same right was worth $100 per acre, and in that period the area of land served by a unit of water was much increased. Accordingly, waste which was permissible under conditions which prevailed in 1898 may not be justified under 1924 conditions, and wasteful practices which may be permissible now are not likely to be allowed in the years to come.

With few exceptions, water for irrigation within the Great Basin is conveyed in earthern ditches. These are located for the most part on porous bench lands which absorb a large quantity of the water as it flows from the source to the place of use. This loss is greatly increased by the existence of too many canals. In many cases one canal could be made to serve the land which is now watered by from 10 to 20 canals. If a dozen or more of these small, poorly built water carriers could be merged into one canal of proper construction and

ample capacity, it would be possible to prevent all but a negligible amount of the current losses. In a few cases large investments have been made in concrete linings for the more porous portions of main canals, but this procedure can not be generally recommended because the lining of some canals might cost more than the water is worth. There are, however, other means of lessening the waste of water and bringing about a more economical use which do not involve much expense.

The most important of these are: (1) The adoption of the most suitable method of irrigation; (2) proper preparation of the surface of fields; (3) the use of large heads and short runs in porous soils; and (4) the application at any one time of no more water than the soil can retain against gravity within the root zone of plants.

In respect to the first suggestion, care should be exercised to adopt a method of applying water that will best meet the conditions of water supply, soils, topography, and crops, and the farm ditches should be located and built in such a way as to conform to the method adopted. The proper preparation of the surface of fields is one of the necessary things in irrigation farming, since every attempt to spread water over a rough, uneven surface results in the waste of water, extra labor in applying it, reduced yields and profits, and, too frequently, damaged soil due to water-logging and the rise of alkali.

An instance of the saving which may be effected in water and labor by the proper preparation of land is reported by R. W. Allen [7], superintendent of the experiment farm at Umatilla, Oreg. Two adjoining 10-acre tracts of alfalfa land of medium sandy soil, having similar topographic conditions, were irrigated by the same man with the same head of water. One tract was carefully prepared, whereas the other was rough and uneven. On the former an average depth of 3½ inches of water was applied at each watering, at a cost of $1.25 for the tract, whereas on the latter 16.8 inches was applied at a cost of $5.90.

Instances in which yields and profits have been reduced by over-irrigating the low parts of a field, although the high parts remained unwatered, are so common as to need little comment. Packard, in writing of alfalfa in Imperial Valley, Calif.,[8] states that "the number of cuttings and the yields secured from an established stand of alfalfa depend almost entirely upon the efficiency of irrigation," and this in turn depends upon how well the surface has been prepared for irrigation.

In preparing land for irrigation, where the soil and subsoil are porous and absorb water readily, a common mistake is to run water too far from head ditches. The length of run should be short where excessive deep percolation is likely to occur. The effect of the length of run on the quantity of water applied, the time required for its application, and the crop yields on the porous, gravelly soils of the Snake River Valley, near Rigby, Idaho, was shown by experiments conducted by the Bureau of Public Roads, in cooperation with the State Land Board of Idaho, during the seasons of 1910 1911, and 1912.

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[7] Circular 3, Umatilla (Oreg.) Branch Experiment Station.
[8] Irrigation of Alfalfa in Imperial Valley, by Walter E. Packard, in Bulletin 284, University of California.

The first of the series of three experiments was conducted on a field of red clover 11.6 acres in extent and irrigated in borders. The soil and subsoil are composed of sand, gravel, and cobbles, and are typical of this locality. During the latter part of August, when the second crop of clover was about 14 inches high, a strip of the field 49.5 feet wide and 2,359 feet long was selected for the experiment. This strip was divided into seven equal parts, each 337 feet long, and a head of water of approximately 2¼ cubic feet per second was turned on at the upper end. The stream was allowed to flow uninterruptedly over the entire length of the strip, the time being noted when the advance of the water reached each division. The results are summarized in Table 4.

TABLE 4.—*Time required to irrigate equal subdivisions of a strip of land in red clover near Rigby, Idaho, and the quantity of water applied to each*

No. of division	Length of division	Area of division	Time required to irrigate	Quantity of water applied per acre
	Feet	*Acres*	*Hrs. min.*	*Acre-feet*
1	337	0.3835	1 22	0.2605
2	337	.3835	1 50	.3499
3	337	.3835	2 00	.3818
4	337	.3835	2 30	.4772
5	337	.3835	3 00	.5727
6	337	.3835	6 00	1.1454
7	337	.3835	7 00	1.3363
Totals	2,359	2.6845	23 42	4.5238

An alfalfa field containing 16.5 acres, located 7 miles southwest of Rigby, Idaho, was selected for the second experiment. Formerly this field had been irrigated in three border strips each 2,560 feet long. In order to determine the benefits, if any, to be derived from shorter runs, the middle strip was subdivided into three equal parts by the building of two extra head ditches, thus reducing the run to one-third its former length. The average quantity of water in each irrigation applied to each of the two outer strips was 1.25 acre-feet per acre, while that applied to the middle strip was 0.9 acre-foot per acre, thus effecting a saving in water of 28 per cent and securing a larger yield of alfalfa.

The third experiment was conducted on a 16-acre oat field in the vicinity of the former experiments. The soil and subsoil were similar in character. The field was irrigated by flooding in three parallel border strips 90 feet wide subdivided into different lengths. The length of the run in the first strip was 428 feet, the second 857, and the third 2,570 feet. Each strip was given three irrigations, the first receiving a total of 2.9 acre-feet, the second 3.23 acre-feet, and the third 4.26 acre-feet per acre. The yields of the respective strips were 76.7, 63, and 74.7 bushels of oats.

It is well to bear in mind that the length of run and the quantities of water absorbed by porous soils do not apply to the tight soils, since in applying water to the latter type it is difficult to secure sufficient penetration of moisture. One of the means used in moistening clay soils to the requisite depth is to apply a small head of water to a long border or furrow for a sufficient time to insure proper penetration of the moisture.

Closely related to this subject is the proper quantity of water to apply at each irrigation. This in turn leads to a consideration of how much water soils can retain for the use of plant roots. To spread more water over a field than is needed is as bad a practice as filling bathtubs to overflowing, yet the former is done on hundreds of farms every day of the irrigation season throughout the Great Basin. One of the results of this wasteful practice is the annual expenditure of large sums of money for the drainage of over-irrigated lands. Frank Adams found [9] that the average quantity of water retained in the lighter and more permeable soils of the Sacramento Valley, Calif., was 0.92 acre-inch per acre for each foot in depth of soil, or the equivalent of 5 to 6 acre-inches per acre for 6 feet of soil, whereas the clay soils, because of their great imperviousness, absorbed an average of only 0.37 acre-inch per acre for each foot in depth, this being at the rate of only about 2¼ acre-inches for 6 acre-feet. He found, however, that in the surface foot the light soils retained an average of 1.04 acre-inches per acre-foot of soil as compared with 1.71 acre-inches per acre-foot held by the clay soils, this being in accordance with the well-known fact that clay soils, when thoroughly wetted, will hold much more soil water than soils of coarser or "lighter" texture.

Israelsen and West [10] state: "It is doubtful if an acre of typical upland soil 4 feet deep (in Utah) would retain more than 3 acre-inches of irrigation water". They further state that an average of nearly 3,000 tests, made by Widtsoe and McLaughlin showed that the upper 8 feet of loam soil of the Greenville farm near Logan, Utah, retained a little more than 1 inch of water for each foot of soil, 24 hours after irrigation. The general conclusion reached by Israelsen and West is that soils have the capacity to absorb from one-half to 1½ inches of water per foot of soil, the actual capacity for a given soil depending on its texture and structure. Sandy and gravelly soils retain the smaller quantities and clay loam soils the larger quantities.

In cooperative investigations conducted in Idaho by the Bureau of Public Roads and the State Land Board of Idaho, Bark [11] found that alfalfa grown in metal containers filled with porous soil utilized only about 13 inches of the 80 inches applied in seven irrigations; the balance, amounting to more than 83 per cent of the volume applied, percolated through the 6 feet of soil and was withdrawn from the bottom of the container.

In addition to those briefly discussed in the preceding paragraphs, there are many more conditions which influence the water requirements of crops, but only two of these, viz., the kind of crops grown and the fertility of the soil will be referred to here.

THE KIND OF CROPS

It is a well-established fact that crops differ widely in their water requirements. The quantity of water required to produce a ton of air-dried alfalfa may suffice for the production of 2½ tons of

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[9] Investigations of the Economical Duty of Water for Alfalfa in Sacramento Valley, California. Bul. No. 3, State of California, Department of Engineering.

[10] Israelsen, O. W., and West, F. L., Water-Holding Capacity of Irrigated Soils, Utah Agr. Exp. Sta. Bul. No. 183.

[11] Bark, Don H., Experiments on the Economical Use of Irrigation Water in Idaho, Bul. No. 339, U. S. Dept. of Agr.

some other standard crop of relatively low water requirements. Accordingly it is possible to grade the crops produced in the Great Basin into low, medium, and high water requirements. Such crops as beans, millet, sorghum, and corn belong to the first named grade; wheat, oats, barley, rye, sugar beets, potatoes, and orchards to the second; and the legumes, grasses, rice, and sunflowers to the third grade. In localities where water is scarce, it is often feasible and remunerative for a farmer who practices diversified cropping to raise crops of all three grades and thus reduce the average quantity of water required for the farm. Under present methods of farming in the Great Basin a large percentage of the total irrigated areas is devoted to the raising of alfalfa and this practice calls for a liberal use of water. Notwithstanding the fact that alfalfa forms the basis of most crop rotations and that this product is needed to supplement range feed for livestock, it is reasonably certain that in future years the percentage of the total irrigated area planted to alfalfa will decrease and that there will be a corresponding increase in the percentage of areas devoted to such crops as peas and other vegetables for canning, sugar beets, small fruits, and deciduous orchards. Such a change in crops will demand less water and is likely to increase the farm profits.

THE FERTILITY OF THE SOIL

It is generally true that the richer the soil and the better it is tilled the smaller will be the water requirements for any one crop. Arid soils are well supplied, as a rule, with mineral plant food, but in their uncultivated state they are deficient in decayed vegetable matter. Until this deficiency is supplied by crop rotation, the application of manure, and proper treatment of the soil, the water requirement is reasonably certain to be high. To produce heavy yields from the use of a given quantity of water, the soil in which the crops grow should not only be rich and well tilled but should contain sufficient vegetable matter derived from manure or the roots of legumes to retain the moisture applied in irrigation. The relation between the efficiency of irrigation water and the fertility of the soil in producing crops is shown in Table 5, which gives the yield of each of a number of crops following a leguminous crop or an application of manure and the same crop grown on new or less fertile land. These experiments formed part of the cooperative irrigation investigations carried on in Idaho during 1910 to 1913 by the Bureau of Public Roads and the State Land Board of Idaho.

WATER REQUIREMENTS AS AFFECTED BY STATE, COMMUNITY, AND CORPORATE REGULATIONS

State legislation and control in the interest of the public welfare, decisions of the courts, regulations and methods adopted by community enterprises, and water-right contracts entered into between irrigation companies and consumers, have all exerted an influence upon the quantity of water which can be diverted for definite areas of land, in that they have defined the quantity and have attempted to make actual practice conform thereto. On the whole it may be said that these influences, which in some cases have been the result

of a growing economic pressure, have probably tended to a more economical use than would have resulted without them.

STATUTES AND ADMINISTRATIVE REGULATIONS

Several States have placed a maximum limit upon the quantity of water which may be appropriated for irrigation purposes. Idaho, for example, allows no more than 1 cubic foot per second of normal flow to be diverted for each 50 acres of land, or 5 acre-feet per acre per annum to be diverted for storage purposes, unless it can be shown to the satisfaction of the department of reclamation or the court that a greater quantity is necessary. Nevada's provision is that the diversion for direct irrigation shall not exceed one one-hundredth cubic foot per second for each acre, measured where the main ditch enters or becomes adjacent to the land to be irrigated, due allowance for losses to be made by the State engineer in permitting additional diversions into the ditch; and for storage purposes, not over 4 acre-feet per acre stored in the reservoir, evaporation and transmission losses to be borne by the appropriator. The California law limits the appropriation for the irrigation of uncultivated areas to 2½ acre-feet per acre, but leaves the amount of other appropriations to the discretion of the division of water rights, this provision not yet having been interpreted by the courts. Utah provides no statutory limitations, but states that "beneficial use shall be the basis, the measure, and the limit of all rights to the use of water in this State." The Oregon law has a similar provision.

To bring about a more economical use of water and thus to increase the duty, Nevada and Oregon have statutory provisions permitting water users to rotate in the use of the water to which they are collectively entitled. Utah, as a means of preventing waste, allows a determination or redetermination of water rights, in whole or in part, where it has been found that waste exists.

Opinions differ as to the wisdom of enactments fixing the duty of water. Unquestionably a hard and fast rule is not wise, because of the great variation in water requirements not only in any State but even on many projects, so that a uniform allowance would work hardships in some cases and encourage waste in others. On the other hand, a maximum statutory allowance of, say, 3 acre-feet per acre would be found inadequate in most places for the irrigation of such crops as rice, yet much more than enough for certain other crops, and unless carefully administered might be construed as entitling an appropriator to 3 acre-feet per acre regardless of his requirements. Such a provision as that of Idaho leaves room for a showing in particular cases that more than the maximum is necessary. If any allowance is made by statute, it should be put forth only as a guide and as an expression of public policy in restricting the unnecessary use of water, leaving the actual amount of the appropriation to be fixed by the State administrative body in accordance with the needs of the appropriator and the best interests of the public.

State administrative regulations in allotting and distributing water are necessarily based upon the statutes, but are very important in governing the use of the appropriated waters. The discretion exercised by the State officials in determining water requirements, where they are granted such discretion, may be far-reaching in

influencing an economical use of water. Likewise, the State engineer usually has the discretion of refusing applications that may interfere with a more beneficial use or that may otherwise prove detrimental to the public welfare.

COURT DECISIONS

Litigation over water rights involving determinations of the duty of water began among the Mormon pioneers and has been widespread in all the States of the Great Basin, as well as in other parts of the West. In line with the generally wasteful irrigation practices of the early days, when water was plentiful and could be secured at small cost, the court decisions allotting water were most generous to the litigants at the expense of nonparticipating water users and the public alike. Streams were over-appropriated, and decrees were rendered in many cases for far more water than the stream carried. Quite generally the economical use of water was not considered in establishing the rights of users. As late as 1893 a decision was rendered by the Supreme Court of Oregon[12] that "the quantity of water to be appropriated is to be measured by the capacity of the ditch at its smallest part; that is, at the point where the least water can be carried through it."

But with the increase in the settlement of land and the resulting decrease in available supplies of water, more careful use has become necessary and wasteful methods are frowned upon by the public and the courts. In the famous Oregon case of Hough *v.* Porter,[13] decided in 1909, the court called attention to the more economical use of water made necessary by the scarcity of the supply and stated:

> In this arid country such manner of use must necessarily be adopted as will insure the greatest duty possible for the quantity available. The wasteful methods so common with early settlers can, under the light most favorable to their system of use, be deemed only a privilege permitted merely because it could be exercised without substantial injury to anyone; and no right to such methods of use was acquired thereby.

Throughout the more recent decisions of the higher courts runs an insistence that water be used economically, and a determination that the courts will require "the highest and greatest possible duty from the waters of the State in the interest of agriculture and other useful and beneficial purposes."[14]

In actually determining the duty in individual cases the courts have frequently been hampered by a lack of available information upon water requirements. Opinion evidence has been plentiful, and has often been the only evidence upon which decisions were rendered. The courts more recently have come to refer, in arriving at the duty of water, to the best use in a community, to lands well prepared for irrigation, and to actual tests and experiments as to the proper duty rather than to rely upon guesswork on the part of persons not competent to testify upon the subject.

Another angle from which the courts have attacked the uneconomical use of water has been in passing upon the method of distribution. In Oregon, Idaho, and California decisions have been

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[12] Coventon *v.* Seufert, 32 Pac. 508.
[13] 98 Pac. 1083.
[14] Farmers' Cooperative Ditch Co. *v.* Riverside Irrigation District, Ltd., et al. (Idaho), 102 Pac. 481.

rendered upholding rotation in the use of water by appropriators, riparian proprietors, and enterprises in delivering to consumers, where the continuous use of the divided water supply would result in waste and ineffectual use by the farmers.

In an Idaho case[15] the court, in interpreting the laws of appropriation, held that it is the policy of the law to prevent waste of water and that consequently the water of all claimants must be measured at the point where such water is diverted from the natural channel of the stream from which it is taken.

COMMUNITY REGULATIONS

Irrigation enterprises have usually a definite quantity of water to distribute to their users, but have the power to encourage or compel an economical use through handling its distribution. Irrigation districts are enjoined by the statutes to make rules and regulations governing the beneficial use of water. In Utah the State engineer makes the original allotment of water to each 40 acres or smaller tract if in separate ownership, but the board of directors of the district makes the final allotment after the water supply is definitely known, using the original allotment as a basis. The method of water distribution used by the enterprise is often a potent factor in bringing about a careful use, and the measurement and distribution upon a quantity basis rather than an acreage basis tend to a more economical use. Important also are the vigilance of the water delivery force in detecting waste, and the measures which can be taken to penalize a wasteful irrigator by cutting off his entire supply for a time or at least by reducing the amount of the delivery by the amount of the waste. Some enterprises establish maximum quantities of water which will be delivered to any tract, and others have schedules of maximum deliveries based upon water requirements of land and crops.

WATER-RIGHT CONTRACTS

Contracts between commercial companies and their water users provide, as a rule, for a definite or a maximum quantity of water to be delivered during the irrigation season to a defined area of land and in case of water shortage at any time, the quantity available is to be prorated. In the case of projects operated under the Carey Act, somewhat similar provisions prevail. In most of the Federal reclamation projects the Secretary of the Interior determines the acreage for which one person may obtain water and the quantity of water to be delivered to each acre during the growing season. About two-thirds of the area irrigated in the West is organized under cooperative or mutual stock companies, and in these the quantity of water diverted by each company is divided into as many equal parts as there are shares of stock in the company. Thus a water user who owns 1 per cent of the stock of the company would be entitled to 1 per cent of the total water supply. Thus, too, the water supply, which usually varies in quantity from day to day, is allotted to consumers in proportional parts rather than in any fixed amounts.

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[15] Stickney *v.* Hanrahan et al. 63 Pac. 189.

LANDS TO BE RECLAIMED

The extent of arable lands within the Great Basin which can be reclaimed depends on the water supply and the manner in which it is stored and used. Only a part of the flood flow is stored at present, and the ultimate possibilities of this region in the utilization of land and water can not be said to be reached until all the excess waters which can be economically stored have been so stored. The storage of water for irrigation will also permit of the development of electric energy and a part of this energy can be used to operate pumps, to raise water from underground and other sources, and to drain water-logged lands. It has also been pointed out that a large percentage of the water at present diverted is wasted in conveyance and use. Assuming that the extension of the irrigated area is desirable, efforts should be concentrated along four main lines of endeavor: (1) The storage of flood waters; (2) providing better facilities for the conveyance of water and adopting better methods in its use; (3) the development of underground water supplies; and (4) the drainage of water-logged lands.

What is possible of accomplishment under these several lines is difficult to estimate, but it is safe to predict that in time it will amount to a doubling of the area now irrigated.

According to the census of 1920, the area irrigated in the Great Basin in 1919 was 2,313,163 acres. Since 1919 was a year of low rainfall and small stream flow, this figure probably should be increased to at least 2,500,000 acres to represent normal conditions as regards water supply at that time. A doubling of this area by the means outlined would therefore increase the reclaimed area to 5,000,000 acres.

The Great Basin, 38 per cent larger than the State of California, has important interests apart from irrigation which should be maintained and enlarged. Chief of these are the mines, hydroelectric plants, grazing areas, transportation facilities, manufactures, and the welfare of urban populations. All of these and more that might be named are more or less directly dependent upon the products of the irrigated farms, and if these other interests are to advance, it will be necessary to maintain a corresponding rate of progress in irrigated agriculture.

Up to the present the rate of progress in irrigation development in this territory may be roughly indicated by stating that 2,500,000 acres have been reclaimed in 75 years. Since such progress in the future is not likely to surpass that of the past, it is reasonable to conclude that another 75 years may pass before an additional 2,500,000 acres is irrigated. Providing a water supply for this area at the present time would call for an expenditure of more than $150,000,000, of which the greater part would be for the storage of flood waters. The building of large dams to retain water for agricultural production and the development of power, on account of the costs involved, is likely to extend over so long a period of time that succeeding generations may have to perform part of the work. Meanwhile a part of the flood flow of streams may be utilized with profitable results by early spring irrigations. Instead of permitting the waste of such waters, the part that can be used economically should

be diverted and applied to arable lands. Many of the results of experiments herein reported show that profitable yields of many of the standard crops can be produced with relatively small quantities of water. To be most effective, this water should be applied at the stage of growth when it will be of greatest benefit, but without storage this practice is not always possible and too often the farmer's choice lies between an early spring irrigation or none at all.

SEASONAL NET WATER REQUIREMENTS OF THE ARABLE LANDS OF EACH SUBDIVISION OF THE GREAT BASIN

By way of conclusion, an estimate has been made, based on the data available, of the seasonal net water requirements of the crops produced and that may be produced in the Basin. This estimate is intended to apply mainly to the lands to be reclaimed by irrigation. In order to take cognizance of the varying conditions which affect water requirements and at the same time recognize geographic position and similarity of climate, products, and types of farming, the Basin has been separated into 12 subdivisions by placing in the same subdivision as far as practicable all of the contiguous arable lands requiring similar quantities of water for profitable crop production. (See fig. 15.)

The net requirements of any farm or other tract of land represent the quantity of water (expressed in acre-feet per acre) which is needed in any one crop-growing season. This quantity is exclusive of all transmission and other losses which may occur between the source of supply and the margin of the farm, and contemplates the recovery by pumping of water lost by deep percolation in the upper lands.

In computing the acreage of irrigable lands on which the water is to be used no deductions have been made for unirrigated portions. Such portions are made up of the spaces occupied by lanes and roads, building sites, corrals, fences, ditches, and land which for one reason or another is not irrigated every year. These nonirrigated portions amount, as a rule, to about 25 per cent of the total irrigable area. Accordingly the transmission losses which occur in conveying water to a farm may be offset by the reduction of the area on which the water is applied. So, too, if the transmission losses do not exceed 25 per cent of the total quantity admitted through the intake, the intake requirements at the river will not exceed the net requirements on the farms. In other words, the reduction in the quantity of water needed, owing to the difference between the gross and net areas, compensates, in a measure, for the loss of water in conveyance.

The net water requirements as given in Table 6 for each division of territory are likewise based on the character and amount of the supplementary rainfall during the growing period, the character of the soil and subsoil, the kind of crops raised, the adoption of suitable methods of applying water, the proper preparation of the land surface, and the exclusion of all run-off and a reasonably small, deep percolation loss.

It may be stated that in making these estimates the furnishing of sufficient water for maximum yields has not been the main object sought. The results of experimentation show that the yields of many crops can be increased by the application of excessive quan-

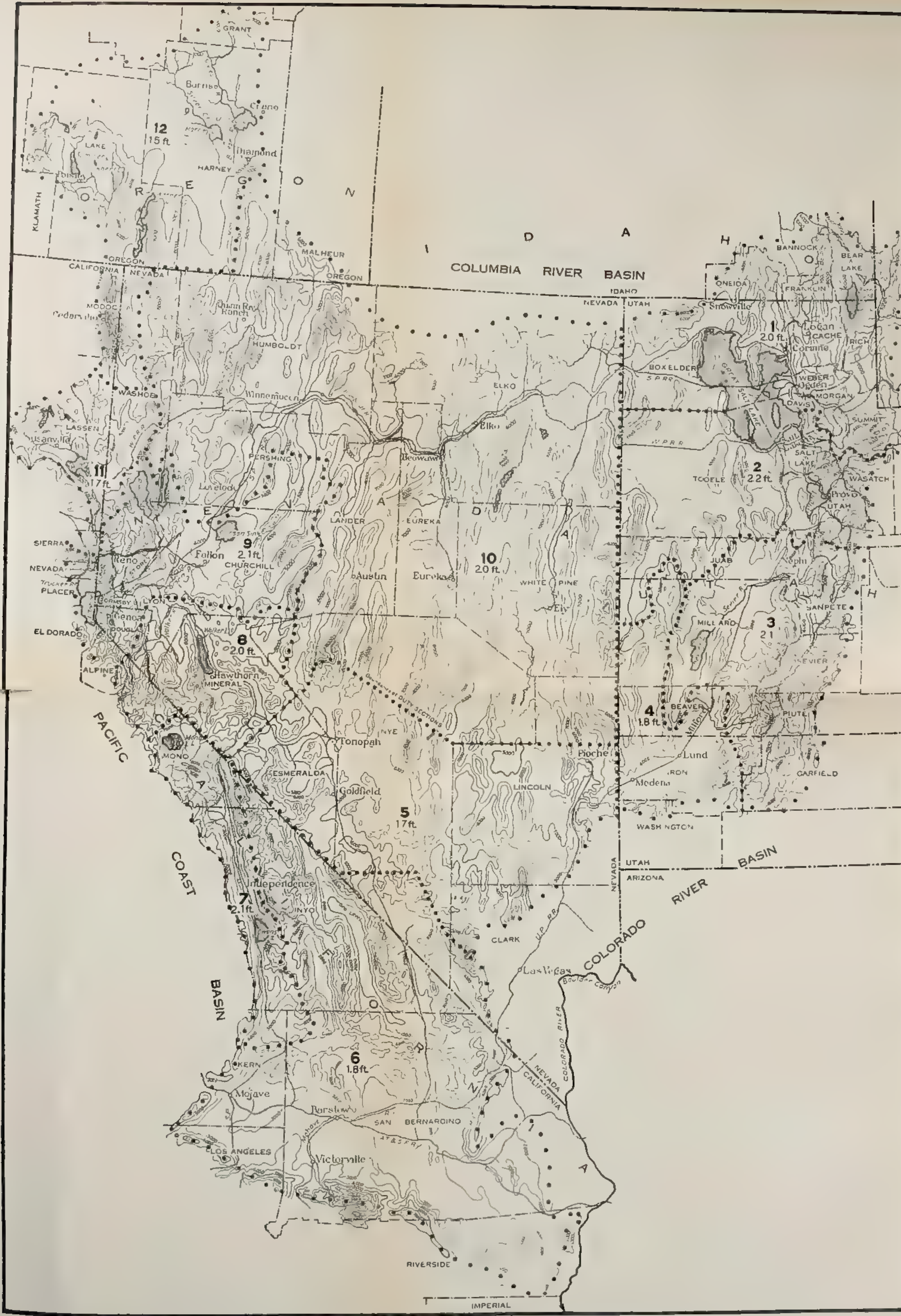

Fig. 15—Map of the Great Basin showing the various duty-of-water division (bounded by dotted lines) with net water requirements of each

tities of water. When one considers, however, the value of irrigation water, the time required to irrigate, and the damage which the waste water resulting from overirrigation is likely to cause in waterlogging soils and causing alkali to rise into the root zone, it is seldom that such a practice is justified from an economical point of view. Such a practice is also at variance with a wise public policy. In the Great Basin, for every acre that eventually is irrigated with the limited water supply at least 6 acres of arable land must remain dry and barren. In view of the abundance of arable land and the shortage of water, it has been deemed advisable to limit the use of water to the actual requirements for profitable crops.

In a few cases the net requirements have been placed below this limit on account of the extreme scarcity of water in certain localities coupled with the possibility of growing crops that require little water, providing the climate is suitable. To illustrate: Deciduous fruit trees, vines, corn, beans, millet, and sorghum may be grown successfully with the use of 35 to 50 per cent of the water required for alfalfa.

Many who are familiar with the present methods of using water in the Great Basin will consider as too low the seasonal net requirements given in the table. Such an opinion is well founded if the present wasteful methods of use are to continue and no further effort is made to store the flood waters. It will be noted that the figures given are based on an economical use, a regulated water supply and the reuse of waste water wherever feasible. If crops can be supplied with water at the time of need, from surface run-off, ground water, or storage reservoirs, and without undue waste, it is believed the conclusions reached in this bulletin will pave the way for the largest agricultural development possible with the extremely small available water supply.

In the economical design of irrigation works it is of outstanding importance to know the largest quantity of water that will be required during any monthly period of the irrigation season. As an aid to good practice in this respect, an estimate has been made, based on regulated stream flow, of the percentage of the total seasonal water requirements that is likely to be required in each month of the period of water delivery. These percentages for each subdivision are given in the appendix in Table 6.

USE OF WATER ON CROPS IN THE GREAT BASIN

All the reliable records available pertaining to the measured use of water on crops in the Great Basin have been compiled and are herein appended in the form of tables. These tables give the seasonal use of water on plots and fields and the monthly use on other plots and fields. The results of use and duty of water experiments have been obtained from the following sources:

(1) Unpublished reports on this subject prepared by members of the Division of Agricultural Engineering, Bureau of Public Roads, United States Department of Agriculture.

(2) Unpublished reports of cooperative irrigation investigations.

(3) Published reports of the Utah, Nevada, and Oregon agricultural experiment stations.

(4) Published reports of the Office of Experiment Stations, the Office of Public Roads and Rural Engineering, and the Bureau of Public Roads of the United States Department of Agriculture.

(5) Published and unpublished reports from the Bureau of Reclamation, United States Department of the Interior.

(6) Irrigation Requirements of California Lands, Appendix B, Water Resources Report, California Department of Public Works.

TABLE 5.—*Showing effect of fertility on yield produced and water requirements in Idaho, 1910–1913*

Year	Crop	Locality	Area	Depth of water applied	Yield		Class of soil and previous treatment
					Per acre	Per acre-foot	
			Acres	*Feet*	*Bushels*	*Bushels*	
1911	Dicklow wheat	Filer	3.59	0.635	63.2	99.5	Alfalfa sod manured.
1911	do	Buhl	5.25	2.15	38.0	17.7	First crop after clearing.
1910	do	do	5.06	1.44	67.2	46.6	Clay loam manured with sheep manure.
1910	do	Gooding	.769	1.84	26.3	14.3	Raw sagebrush clay loam.
1912	do	Kimberley	8.27	1.16	82.9	71.5	Alfalfa sod manured.
1912	do	Buhl	6.09	1.21	24.1	19.9	Fourth year from grain on raw soil.
1911	Oats	Oakley	4.98	.64	76.5	119.0	Alfalfa sod.
1911	do	Twin Falls	4.03	2.26	68.9	30.5	Third crop from sagebrush, unfertilized.
1911	do	Boise	2.37	1.076	73.0	68.0	Two years from clover sod.
1911	do	Richfield	4.15	1.89	50.8	26.9	Two years from sagebrush.
1912	Wheat	Boise	.165	1.04	54.5	52.3	Two years from clover sod.
1912	do	Meridian	13.36	2.47	31.2	12.6	Cropped 10 years without fertilization.
1912	Big Four oats	Gooding Experiment Station.	.53	2.04	106.3	52.2	Manured.
1913	do	do	.49	2.7	66.0	24.4	Fourth crop from brush, no fertilization.
1912	Coast barley	do	.31	1.52	90.0	59.3	First year from alfalfa sod.
1913	do	do	.74	2.75	32.8	11.9	Fourth crop from brush, no fertilizer.
1912	Turkey winter wheat.	do	.69	.64	39.4	61.6	Manured lightly.
1910	do	do	.96	.81	23.0	28.4	Second crop from sagebrush.

TABLE 6.—*Monthly and seasonal net water requirements of the various subdivisions of the Great Basin*

No. of division	Description of division	Monthly percentages of total seasonal net requirements								Seasonal net water requirement in acre-feet per acre
		Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	
1	Bear River basin in southeastern Idaho and northern Utah			8	25	30	22	11	4	2.0
2	Utah Lake and Great Salt Lake Valleys south of Weber River basin			10	24	28	20	14	4	2.2
3	Sevier River basin			10	23	28	22	14	3	2.1
4	Irrigable lands of southwestern Utah		6	14	22	26	20	10	2	1.8
5	Irrigable lands of southern Nevada		8	14	20	22	18	12	6	1.7
6	Antelope Valley and Mohave River areas [1]	3	10	16	18	20	18	10	5	1.8
7	Mono, Owens and Inyo-Kern valleys [1]	2	10	16	20	20	18	10	4	2.1
8	Walker River basin		2	14	22	26	20	12	4	2.0
9	Truckee River and Carson River basins			14	24	28	20	12	2	2.1
10	Humboldt, Quinn, and White River basins			15	25	30	20	10		2.0
11	Honey Lake basin		3	14	24	26	21	12		1.7
12	Malheur Lake, Harney Lake, and other basins in Oregon		4	16	26	28	18	8		1.5

[1] See Irrigation Requirements of California Lands, Bul. No. 6 Calif. State Dept. of Public Works.

APPENDIX

TABLE 7.—*Use of water on crops in the Great Basin. Irrigation water applied, rainfall, and crop yields in experiments at Logan, Utah* [1]

SUGAR BEETS

Each plot contained 0.03793 acre

Year	Number of irrigations	Monthly application of water						Total quantity of water received by crop			Yield per acre
		Apr.	May	June	July	Aug.	Sept.	Irrigation	Rainfall	Total	
		Inches	*Inches*	*Inches*	*Inches*	*Inches*	*Inches*	*Feet*	*Feet*	*Feet*	*Tons*
1904	3			1.25		4.52		0.49	0.50	0.99	16.96
1904	3			1.25		4.52		.49	.50	.99	14.61
1904	4			1.12		4.52		.47	.50	.97	16.91
1904	4			1.13		4.52		.47	.50	.97	12.78
1904	4			1.12		4.52		.47	.50	.97	13.09
1904	3			1.12		4.52		.47	.50	.97	16.23
1904	3			1.12		4.52		.47	.50	.97	15.92
1904	3			1.12		4.52		.47	.50	.97	18.39
1904	3			1.12		4.78		.49	.50	.99	17.69
1904	4			1.12		4.89		.50	.50	1.	16.88
1904	3			1.12		4.52		.47	.50	.97	18.35
1904	3			1.12		4.52		.47	.50	.97	20.78
1904	4			1.12		4.52		.47	.50	.97	19.89
1904	4			1.12		4.52		.47	.50	.97	17.78
1904	4			1.12		4.52		.47	.50	.97	12.20
1904	4			1.12		4.52		.47	.50	.97	15.16
1904	4			1.12		4.52		.47	.50	.97	17.40
1904	4			1.12		4.52		.47	.50	.97	15.96
1904	3			1.12		4.52		.47	.50	.97	17.30
1905	4			2.5	6.26			.72	.50	1.22	15.46
1905	6			3.75	7.5	7.5	3.75	1.87	.50	2.37	17.95
1905	4				6.06	8.05		1.17	.50	1.67	12.57
9015	4				8.18	4.57		1.06	.50	1.56	13.11
1905	4				6.37	7.23		1.13	.50	1.63	12.15
1905	1				2.5			.21	.50	.71	6.65
1905	2				2.5	2.5		.42	.50	.92	9.05
1905	2				3.75	3.75		.62	.50	1.12	12.01
1905	4			2.5	6.26			.72	.50	1.22	15.46
1905	3			3.75	3.97	1.49		.77	.50	1.27	11.42
1905	7			5	10.	2.50		1.45	.50	1.95	19.67
1905	5			7.50	11.25			1.56	.50	2.06	19,36
1905	6			2.50	5	5.	2.50	1.25	.50	1.75	15.21
1906	4				13.46	11.59		2.09	1.12	3.21	25.6
1906	3				10.05	5		1.25	1.12	2.37	28.8
1906	2				5	5		.83	1.12	1.95	29.2
1906	1					5		.42	1.12	1.54	25.2
1906	4				7	7		1.16	1.12	2.28	26.7
1906	3				5	4		.75	1.12	1.87	26.5

[1] These plot experiments were carried on under cooperative agreements between the Division of Agricultural Engineering, Bureau of Public Roads, United States Department of Agriculture and the Utah Agricultural Experiment Station on the Greenville Farm, the property of the Utah Agricultural College located 2 miles north of Logan, Utah.

The plots were 29 feet wide by 57 feet long and contained nearly 0.03793 of an acre. The computations as regards the quantity of water used were based upon the actual size of each plot.

Considering the variety of soils to be found on most tracts, the soil of the Greenville farm is uniform in texture, consists mainly of sand and silt, is of great depth and is far removed from a water table.

POTATOES

										Bushels
1904	3		5.76	10.47			1.35	0.50	1.85	347.4
1904	9		3.97	15.05	15.13		2.84	.50	3.34	422.9
1904	4		5.05	10	5		1.67	.50	2.17	352.24
1904	4		5.05	5	5		1.25	.50	1.75	325
1904	4		5.05	5	10		1.67	.50	2.17	285
1904	4		5.05	5	10		1.67	.50	2.17	299
1904	4		5.05	5	10		1.67	.50	2.17	321.9
1904	4		5.05	5	10		1.67	.50	2.17	346.3
1904	8			7.50	7.50	7.50	1.87	.50	2.37	398.79
1904	5		7.50	15	15		3.12	.50	3.62	380.79
1904	5			7.5	3.75	7.50	1.55	.50	2.05	365.85
1904	3		7.5	7.5	7.5		1.87	.50	2.37	326.76
1905	4		7.5	15	4.66		2.26	.49	2.75	330.2

TABLE 7.—*Use of water on crops in the Great Basin, etc.*—Continued

POTATOES—Continued

Year	Number of irrigations	Monthly application of water						Total quantity of water received by crop			Yield per acre
		Apr.	May	June	July	Aug.	Sept.	Irrigation	Rainfall	Total	
		Inches	*Inches*	*Inches*	*Inches*	*Inches*	*Inches*	*Feet*	*Feet*	*Feet*	*Bushels*
1905	6			3.75	7.5	7.5	3.75	1.87	.49	2.36	331.6
1905	4			10	10			1.66	.49	2.15	336.2
1905	4			10	10			1.66	.49	2.15	383.3
1905	4			10	10			1.66	.49	2.15	286
1905	4			10	10			1.66	.49	2.15	314
1905	4			10	10			1.66	.49	2.15	305.9
1905	4			10	10			1.66	.49	2.15	306.8
1905	4			22.50	7.5			2.50	.49	2.99	377.5
1905	6			11.25	7.50	3.75		1.87	.50	2.37	265.3
1905	7				5	15	10	2.50	.50	2.00	384
1905	4					7.47	7.5	1.25	.50	1.75	231

BROME

Year	Number of irrigations	Apr.	May	June	July	Aug.	Sept.	Irrigation	Rainfall	Total	Yield per acre
											Tons
1904	1			8.75				0.75			4.16
1904	2			8.75		3.50		1.02			4.02
1904	6			28.48	7.50	7.50		3.61			3.59
1905	2			11.35	7.5			1.57	0.37	1.94	1.95
1905	1			7.50				.61	.37	.98	2.14
1905	6			36.87	15			4.31	.37	4.68	1.53

TIMOTHY

Year	Number of irrigations	Apr.	May	June	July	Aug.	Sept.	Irrigation	Rainfall	Total	Yield per acre
1904	5			19.77	7.5	7.51		2.88			3.35
1904	1			7.25				.60			1.55
1904	1			7.25				.60			1.63
1905	6			36.55	15			4.31	0.37	4.68	1.11
1905	2			11.35	7.50			1.57	.37	1.94	1.71
1905	1			7.50				.61	.37	.98	2.42

ALFALFA

Year	Number of irrigations	Apr.	May	June	July	Aug.	Sept.	Irrigation	Rainfall	Total	Yield per acre
1904	6			15	15	12.5		3.54	0.50	4.04	7.28
1904	4			5	5	12.50		1.87	.50	2.37	5.57
1904	4			7.5	5	7.50		1.66	.50	2.16	5.06
1904	4			7.5	11.25	3.75		1.87	.50	2.37	5.23
1905	7			31.69	32.47			5.34	.37	5.71	6.95
1905	4			6.25	6.25	16.58		2.42	.37	2.79	5.69
1905	4			6.25	12.5	6.25		2.08	.37	2.45	5.56
1905	4			3.75	6.57	19.75		2.51	.37	2.88	4.97
1905	4			8.43	13.30	6.25		2.33	.37	2.70	4.28

ALFALFA SEED AND HAY

Year	Number of irrigations	Apr.	May	June	July	Aug.	Sept.	Irrigation	Rainfall	Total	Yield per acre
1906	5			7.69	18.92	5.83		2.70	0.61	3.31	2.58 [2] 115
1906	5			5	15	5		2.08	.61	2.69	2.5 [2] 120
1906	4			5	10	5		1.66	.61	2.27	2.37 [2] 111
1906	3			5	5	5		1.25	.61	1.86	2.5 [2] 125
1906	2				5	5		.83	.61	1.44	2.2 [2] 116
1906	7			17.5	30	10	10	5.62	.60	6.22	6.57
1906	7			12.5	22.5	7.5	7.5	4.16	.60	4.76	5.83
1906	7			15.5	22.5	7.5	7.5	4.42	.60	5.02	5.62
1906	7			7.5	15	5	5	2.70	.60	3.30	4.69

[2] Bushels.

TABLE 7.—*Use of water on crops in the Great Basin, etc.*—Continued

CORN

Year	Number of irrigations	Monthly application of water						Total quantity of water received by crop			Yield per acre
		Apr.	May	June	July	Aug.	Sept.	Irrigation	Rainfall	Total	
		Inches	*Inches*	*Inches*	*Inches*	*Inches*	*Inches*	*Feet*	*Feet*	*Feet*	*Bushels*
1904	9				15	22.0		3.18	0.50	3.68	119.34
1904	8				7.5	11.25		1.56	.50	2.06	117.08
1904	16			6	24.95	17.5		4.03	.50	4.53	124.61
1904	4			5	8	5		1.50	.50	2.00	129.13
1904	11			13.26	19.97	20		4.43	.50	4.93	117.46
1904	4			5.25	10.17	5		1.70	.50	2.20	117.46
1905	6			5	15			1.67	.49	2.16	87.33
1905	5				8.98	10		1.58	.49	2.07	76.04
1905	7			5	15	15		2.92	.49	3.41	80.18
1905	4				10	10		1.66	.49	2.15	62.11
1905	5				5	20		2.08	.49	2.57	78.67
1905	7			2.61	5.76	10.08		1.54	.49	2.03	161.64
1905	3				5	10.67		1.31	.49	1.80	89.59
1905	3				5	10		1.25	.49	1.74	33.12
1905	3				15	7.50		1.87	.49	2.36	90.73
1905	5				7.5	7.5	3.75	1.56	.49	2.05	77.17
1906	3				5	5	5	1.25	1.10	2.35	85.45
1906	4				3.14	6	3	1.01	1.10	2.11	80.56
1906	4				10	5	5	1.66	1.10	2.76	84.32

ITALIAN RYE GRASS

Year	Number of irrigations	Apr.	May	June	July	Aug.	Sept.	Irrigation	Rainfall	Total	Yield per acre
											Tons
1904	6			31	7.5	7.5		3.83	0.50	4.33	1.98
1904	1			15.44				1.29	.50	1.79	1.90
1904	1			7.94				.66	.50	1.16	1.73
1905	6			25.24	15			3.35	.49	3.84	1.06
1905	2			19				1.58	.49	2.07	.82
1905	1			7.5				.62	.49	1.11	.63

ORCHARD GRASS

Year	Number of irrigations	Apr.	May	June	July	Aug.	Sept.	Irrigation	Rainfall	Total	Yield per acre
1904	6			30.5	7.5	7.5		3.79	0.50	4.29	2.02
1904	1			7.94				.66	.50	1.16	1.61
1905	6			26.8	22.5			4.10	.49	4.59	.60
1905	2			18				1.50	.49	1.99	1.21

CORN FODDER

Year	Number of irrigations	Apr.	May	June	July	Aug.	Sept.	Irrigation	Rainfall	Total	Yield per acre
1906	2				10			0.83	1.10	1.93	5
1906	3				15			1.25	1.10	2.35	6.2
1906	4			5	15			1.66	1.10	2.76	5.8

WHEAT

Year	Number of irrigations	Apr.	May	June	July	Aug.	Sept.	Irrigation	Rainfall	Total	Yield per acre
											Bushels
1905	3			8.72	10			1.56	0.39	1.95	51.82
1905	3			5	10			1.25	.39	1.64	46.12
1905	3			5	10			1.25	.39	1.64	45.24
1906	2			5	3.7			.73	1.06	1.79	58.75
1906	3			5.6	10			1.30	1.06	2.36	53.14
1906	3			3.8	5			1.15	1.06	2.21	54.46
1904	3			5	9.57			1.22			54.46
1904	1			3.75				.31			45.68
1904	4			5	10			1.25			43.92
1904	3			5	8.12			1.09			42,82
1904	4			5	4.99			.83			45.02
1904	2			14.3	4.85			1.59			35.57
1904	5			9.87	5.11	10.00		2.08			43.04
1904	10			10	21.5	7.50		3.25			54.
1904	7			10	15	10.		2.92			58.19
1904	7			5	15	5.		2.08			54.

TABLE 7.—*Use of water on crops in the Great Basin, etc.*—Continued

WHEAT—Continued

Year	Number of irrigations	Monthly application of water						Total quantity of water received by crop			Yield per acre
		Apr.	May	June	July	Aug.	Sept.	Irrigation	Rainfall	Total	
		Inches	*Inches*	*Inches*	*Inches*	*Inches*	*Inches*	*Feet*	*Feet*	*Feet*	*Tons*
1904	7			5	15	5.		2.08			53.
1904	4			5	10	5.		1.66			51.61
1904	3			5	10			1.25			53.14
1904	2			5	5			.83			48.75
1904	1				5			.42			42.82
1904	3			5	9			1.17			54.46
1904	3			5	5			.83			50.07
1904	1				3.75			.31			38.
1904	2				10			.83			45.9
1904	2				10			.83			47.65
1904	2				10			.83			43.48
1904	3			5.37	6.66			1.00			42.04
1904	3			3.57	7.50			.91			47.
1904	9			12.98	15	18.5		3.87			60.83
1904	4			5	10			1.25			56.66
1905	6			24.56	6.67			2.60	0.39	2.99	57.53
1905	3			5	10			1.25	.39	1.64	50.1
1905	3			6.61	10.04			1.39	.39	1.78	50.1
1905	1			3.75				.31	.39	.70	42.16
1905	3			5	10			1.25	.39	1.64	42.16
1905	3			5	10			1.25	.39	1.64	53.38
1905	2			7.5	2.5			.83	.39	1.22	43.48
1905	3		0.39	.82	.37			.13	.39	.52	38.38
1905	2			2.5	7.5			.83	.39	1.22	49.19
1905	3			5	5			.83	.39	1.22	44.5
1905	2			3.33	6.67			.83	.39	1.22	54.02
1905	5			10	10			1.66	.39	2.05	49.19
1905	2			2.5	2.5			.41	.39	.80	38.46
1905	3			5	10			1.25	.39	1.64	40.85
1905	3			5	10			1.25	.39	1.64	46.12

BEANS

Year	Number of irrigations	Apr.	May	June	July	Aug.	Sept.	Irrigation	Rainfall	Total	Yield per acre
1905	12			6.36	13.13	18.75		3.19	0.39	3.58	16.68
1905	5			3.75	11.51			1.27	.39	1.66	19.32
1905	5			3.75	7.50	7.50		1.56	.39	1.95	19.32
1905	3			3.75	3.75	3.75		.94	.39	1.33	10.98
1905	7			3.75	11.25	11.25		2.19	.39	2.58	5.80
1905	8			7.5	18.75	3.75		2.50	.39	2.89	4.07
1906	2				8.17			.68	1.01	1.69	28.5
1906	4				15	5		1.66	1.01	2.67	38.64
1006	6				19.24	10.65		2.49	1.01	3.50	39.96

BARLEY

Year	Number of irrigations	Apr.	May	June	July	Aug.	Sept.	Irrigation	Rainfall	Total	Yield per acre
1904	6			8.26	15.84	3		2.26	.46	2.72	72.19
1904	4			5.6	15.50			1.76	.46	2.22	66.15
1904	3			10	5			1.25	.46	1.71	67.23
1904	2			3.75	3.75			.63	.46	1.09	66.15
1905	5			15.5	24			3.29	.39	3.68	62.59
1905	4			13.75	13.75			2.29	.39	2.68	63.13
1905	3			7.15	11.70			1.56	.39	1.95	68.08
1905	2			2.5	4.99			.62	.39	1.01	71.37

TABLE 7.—*Use of water on crops in the Great Basin, etc.*—Continued

CABBAGE

Year	Number of irrigations	Monthly application of water						Total quantity of water received by crop			Yield per acre
		Apr.	May	June	July	Aug.	Sept.	Irrigation.	Rainfall	Total	
		Inches	*Inches.*	*Inches.*	*Inches.*	*Inches.*	*Inches.*	*Feet*	*Feet*	*Feet*	*Pounds*
1904	1			2.5				0.21			13,240
1904	2			2.5				.21			15,602
1904	3			9.72				.81			24,510
1905	8			15	5	15		2.91	.33	3.24	15,340
1905	8			7.5	7.5		2.5	1.45	.33	1.78	17,440
1905	6			9.99	7.73			1.48	.33	1.81	12,400
1905	7			5	5	5		1.25	.33	1.58	9,900
1905	5			9.64	7.3	5.16		1.84	.33	2.17	5,440
1905	7			7.5	10			1.45	.33	1.78	17,380
1905	5			10	10	5		2.08	.33	2.41	14,180
1906	4			6	12	6		2.00	1.06	3.06	21,780
1906	4			4.5	9	4.5		1.50	2.56	4.06	24,560
1906	4			3.35	6	3		1.03	1.06	2.09	27,080
1906	6			3.7	9	6		1.56	1.06	2.62	29,020

ONIONS

Year	Number of irrigations	Apr.	May	June	July	Aug.	Sept.	Irrigation.	Rainfall	Total	Yield per acre
											Tons
1904	2			5.07	5.07			0.84			5.43
1904	3			5.11	10.13			1.26			7.25
1904	6			7.50	10.0			1.46			3.02
1904	7			2.50	12.81			1.28			3.55
1904	6			5	12.50	2.50		1.66			4.11
1904	8			10	15			2.08			5.74
1904	9			15	15.50	20		4.20			9.35
1905	14			5.5	4.12	9.62		1.60	0.56	2.16	22.77
1905	9			13.03	6.97	15	3.03	3.17	.56	3.73	22.19
1905	7			7.5	10			1.45	.56	2.01	20.86
1905	5			8.03	11.97			1.66	.56	2.22	17.79
1905	7			5.0	5	5	2.5	1.45	.56	2.01	11.40
1905	5			2.5	5	7.5	7.5	1.87	.56	2.43	24.60
1905	7			7.50	10			1.45	.56	2.01	
1905	7			10	10	10	5	2.91	.56	3.47	
1906	7			7.42	12	12	6	3.12	1.06	4.18	14.80
1906	8			6.96	9	13.5		2.45	1.06	3.51	13.82
1906	6			3.59	6	6	3	1.55	1.06	2.61	11.21
1906	8			3	12	6	3	2	1.06	3.06	10.44

CARROTS

Year	Number of irrigations	Apr.	May	June	July	Aug.	Sept.	Irrigation.	Rainfall	Total	Yield per acre
1904	2			10.5				0.87			21.69
1904	2			8.75				.72			13.69
1904	2			7.5	7.5			1.25			11.87
1904	1			7.5				.62			12.35
1904	4			5.0	10			1.25			19.44
1904	4			7.5	7.5			1.25			13.03
1905	14			6.89	2.75	9.62		1.60	0.56	2.16	23.4
1905	10			15.00	5.0	18.62		3.22	.56	3.78	26.59
1905	7			7.50	10			1.45	.56	2.01	28.
1905	6			15.00	7.5		7.5	2.50	.56	3.06	27.92
1905	5			10	10			1.66	.56	2.22	30.06
1905	4			7.5	7.5	7.5	7.5	2.50	.56	3.06	19.31
1905	1			7.5				.62	.56	1.18	13.23
1905	3			7.5	7.5			1.25	.56	1.81	13.26
1905	1			3.75				.31	.56	.87	13.75
1905	7			7.5	10			1.45	.56	2.01	31.45
1905	7			10	10	10	5	2.91	.56	3.47	24.17
1906	6			6	12	12	6	3.00	1.06	4.06	30.85
1906	5				9.0	9.0	4.5	1.86	1.06	2.92	29.38
1906	5			3	3	6	3	1.25	1.06	2.31	31.24
1906	8			3	12	6	3	2.00	1.06	3.06	25.20
1906	6			4.5	9	9	4.5	2.25	1.06	3.31	26.12

TABLE 8.—*Use of water on crops in the Great Basin, irrigation water applied, rainfall, and crop yields in Oregon*

ALFALFA, CHEWAUCAN VALLEY

[From Oregon Agricultural Experiment Station Bulletins 140 and 189]

Year	Area irrigated	Quantity of water received by crop			Yield per acre
		Irrigation	Rainfall	Total	
	Acres	*Feet*	*Feet*	*Feet*	*Tons*
1916	2.53	2.66			6.10
1916	3.16	1.78			4.39
1916	2.38	.93			4.37
1917	1.59	1.06			.86
1917	1.65	.82			1.29
1917	1.46	.46			1.09
1917	1.0	8.25			1.7
1917	1.0	2.50			1.43
1917	1.0	1.17			1.06

ALFALFA, HARNEY VALLEY

1919	0.1	0.64			1.13
1919	.1	.97			2.36
1919	.1	1.31			3.61
1919	.1	.64			1.96
1919	.1	.97			2.67
1919	.1	1.31			2.97
1920	.1	.58			4.94
1920	.1	.83			3.07
1920	.1	1.0			2.55
1920	.1	.58			5.0
1920	.1	.83			2.42
1920	.1	1.17			5.9

ALFALFA, CHEWAUCAN VALLEY

1920	2.53	1.39			3.1
1920	3.16	1.03			2.24
1920	2.38	.51			2.32
1916	2.53	2.68	0.42	3.10	6.1
1916	3.16	1.76	.56	2.32	4.4
1916	2.38	.93	.67	1.60	4.4
1916	1.1	1.03	.28	1.31	.86
1916	1.1	.82	.37	1.19	1.29
1916	1.1	.46	.55	1.01	1.09

ALFALFA (ROWS), HARNEY VALLEY

1916		1.50	0.08	1.58	2.16
1916		1.0	.37	1.37	2.64
1916		.50	.53	1.03	2.08

NOTE.—The soils of Chewaucan Valley range from a very fine, sandy loam to a very stiff, silty clay which is hard to work and of low water-holding capacity. The lighter soils, however, are productive, easily worked and of good water-holding capacity.

The soils of the Harney Valley are varied but silt predominates, being about 4 to 6 feet deep, with a sandy subsoil, and are easily worked, also grow excellent crops.

The crops grown in these valleys are hay and grain.

TABLE 9.—*Use of water on crops in the Great Basin, irrigation water applied, rainfall, and crop yields in Oregon*

Year	Area irrigated	Quantity of water received by crop			Yield per acre
		Irrigation	Rainfall	Total	
MARSH GRASS, CHEWAUCAN VALLEY [1]					
[From Oregon Agricultural Experiment Station Bulletin 140]					
	Acres	*Feet*	*Feet*	*Feet*	*Tons*
1915	0.1	2.38	0.47	2.85	0.89
1915	.1	.94	.26	1.20	1.03
1915	.1		.28	.28	.57
1915	.1	1.51	.54	2.05	.70
1915	.1	.55	.42	.97	.73
1916	.1		.36	.36	.70
CLOVER AND TIMOTHY, CHEWAUCAN VALLEY [1]					
1916	0.1	0.35	0.22	0.57	2.6
1916	.1	.26	.22	.48	2.1
1916	.1	.19	.21	.40	2.4
NATURAL MEADOW HAY, CHEWAUCAN VALLEY [2]					
1916	0.1	2.21	0.58	2.79	1.5
1916	.1	1.60	.66	2.26	1.9
1916	.1	.71	.72	1.43	1.2
NATURAL MEADOW HAY, HARNEY VALLEY [3]					
1916		1.79	1.04	2.83	2.18
1916		.90	1.25	2.15	2.18
1916			.83	.83	2.18
1916		2.04	.57	2.61	1.96
1916		1.04	.83	1.87	1.96
1916			.50	.50	2.[illegible]1
1916		2.33	.93	3.26	2.[illegible]3
1916		1.17	.91	2.08	2.[illegible]3
1916			1.05	1.05	1.96
SPRING WHEAT, HARNEY VALLEY [3]					
					Bushels
1916		0.75	0.93	1.68	29.2
1916		.50	.70	1.20	26.7
1916		.25	.82	1.07	22.4
OATS, CHEWAUCAN VALLEY [4]					
1916	1.1	1.56	0.37	1.93	21.8
1916	1.1	1.11	.42	1.53	17.3
1916	1.1	.75	.59	1.34	15.4

[1] The soil of these plots consisted of a silty loam underlaid by a fairly stiff clay and a subsoil of fine, sandy loam.
[2] These plots have a surface soil of peaty loam and a subsoil of fine sandy loam.
[3] Fine sandy loam soil with a subsoil of fine sand.
[4] Silty loam soil on surface, clay beneath, and a subsoil of fine sandy loam.

TABLE 9.—*Use of water on crops in the Great Basin, etc.*—Continued

FIELD PEAS, HARNEY VALLEY

Year	Area irrigated	Quantity of water received by crop			Yield per acre
		Irrigation	Rainfall	Total	
	Acres	*Feet*	*Feet*	*Feet*	*Tons*
1916		1	0.30	1.30	1.69
1916		.67	.12	.79	1.69

CORN, CHEWAUCAN VALLEY

Year	Area irrigated	Irrigation	Rainfall	Total	Yield per acre
					Bushels
1916	1.5	0.48	0.63	1.11	55.5
1916	1.5	.28	.59	.87	43.2
1916	1.5	.16	.62	.78	43.6

SUGAR BEETS, CHEWAUCAN VALLEY

Year	Area irrigated	Irrigation	Rainfall	Total	Yield per acre
					Tons
1916	1.7	1.21	0.33	1.54	36.18
1916	1.7	.84	.33	1.17	37.34
1916	1.7	.17	.33	.50	28.39
1916	1.5	2.21	.33	2.54	12.4
1916	1.5	.87	.38	1.25	12
1916	1.5	.50	.51	1.01	11.2

BARLEY, CHEWAUCAN VALLEY

Year	Area irrigated	Irrigation	Rainfall	Total	Yield per acre
					Bushels
1915	3.71	2.90	0.71	3.61	15.1
1915	2.43	2.81	.53	3.34	35.4
1915	2.40	2.19	.49	2.68	23.3

TABLE 10.—*Use of water on crops in the Great Basin, irrigation water applied, rainfall, and crop yields in Nevada*

WHEAT, TRUCKEE VALLEY

Year	Area irrigated	Number of irrigations	Quantity of water received by crop			Yield per acre
			Irrigation	Rainfall	Total	
	Acres		*Feet*	*Feet*	*Feet*	*Bushels*
1903	1	4	1.85	.18	2.03	48
1903	1	3	1.68	.18	1.86	46
1903	.33	4	1.45	.18	1.63	46
1903	1	3	1.85	.18	2.03	47.9
1904	1	3	1.70	.18	1.88	42.2
1904	1	3	1.42	.18	1.60	35
1904	.5	9	7.03	.18	7.21	46.1
1905	1	4	2.29	.18	2.47	42.3
1905	1	4	1.58	.18	1.76	38.8
1905	.25	2	1.50	.18	1.68	31.6
1905	.25	1	.86	.18	1.04	39.6
1904	0.5	3	1.7			42.3
1904	1.0	3	1.42			34.88
1904	.5	9	7.03			46.3
1904	.5	2	1.85			25.8
1904	.5	2	1.84			21.2
1904	.5	2	1.99			22.9
1905	1.0	4	2.29			42.3
1905	1.0	4	1.58			38.8
1905	.25	2	1.5			31.6
1905	.25	1	.86			39.3
1906	.2	9	2.14			45.6
1906	.2	7	1.97			48.0
1906	.2	4	1.49			57.4
1906	.2	4	1.59			46.1

TABLE 10.— *Use of water on crops in the Great Basin, etc.*—Continued

BARLEY, TRUCKEE VALLEY

Year	Area irrigated	Number of irrigations	Quantity of water received by crop: Irrigation	Quantity of water received by crop: Rainfall	Quantity of water received by crop: Total	Yield per acre
	Acres		*Feet*	*Feet*	*Feet*	*Bushels*
1904	3.0	4	3.75			36.4
1904	1	4	3.35			24
1905	3	4	6.94			26.2
1905	1	5	2.56			30.5
1906	.20	8	1.34			32.8
1906	.20	5	1.28			53.4
1906	.20	3	.93			56.2
1906	.20	2	.99			58.4

OATS, TRUCKEE VALLEY

						Pounds
1904	1	3	1.79			1,599
1904	1	3	1.37			2,034
1905	1	4	2.87			2,440
1905	1	4	1.72			2,352
1906	2	3	1.91			2,588
1906	.20	10	2.15			2,165
1906	.20	7	2.13			3,900
1906	.20	4	1.32			3,952
1906	.20	4	1.43			3,180
1906						540

MACARONI WHEAT, TRUCKEE VALLEY

						Pounds
1905	0.5	18	2.58			2,340
1905	.5	13	2.06			2,286
1905	.5	8	1.45			2,035
1905	.5	7	1.35			2,120
1905	.5	5	1.26			1,060
1905	.5	4	1.00			950
1905	.5	2	.50			450

MANGELS, TRUCKEE VALLEY

						Tons
1904	1	7			5.3	20.03
1905	1	8			3.4	15.84
1906	.20	21			1.73	23.52
1906	.20	8			1.32	16.81
1906	.20	5			1.05	13.15
1906	.20	4			.89	15.47

POTATOES, TRUCKEE VALLEY

						Tons
1904	0.50	5	3.64			9.53
1904	.50	6	4.66			9.
1906	.20	32	1.99			9.56
1906	.20	11	1.66			10.66
1906	.20	5	.95			11.56
1906	.20	5	.84			7.07
1906	.10	1	.16			3.50

NOTE.—The plot experiments pertaining to duty of water in Nevada were carried on for the most part at the Nevada Agricultural Experiment Station located in the Truckee Valley at Reno. In this work there was intermittent cooperation between the Division of Agricultural Engineering and the University of Nevada.

The soil is variable but speaking generally it may be said to be gravelly clay loam underlaid by sand, gravel, and bowlders.

TABLE 11.—*Use of water on crops in the Great Basin, irrigation water applied, rainfall, and crop yields in Nevada*

[From Nev. Agr. Exp. Sta. Bul. 96 and O. E. S. Bul. 104]

Year	Area irrigated	Number of irrigations	Quantity of water received by crop			Yield per acre
			Irrigation	Rainfall	Total	
SUGAR BEETS, NEVADA AGRICULTURAL EXPERIMENT STATION FARM, RENO						
	Acres		*Feet*	*Feet*	*Feet*	*Tons*
1914–15	0.03	7	1.08			9.58
1914–15	.03	5	1.50			11.31
1914–15	.03	4	2			10.70
1914–15	.03	5	.83			9.64
1914–15	.03	4	1.16			9.67
1914–15	.03	3	1.50			11.43
1914–15	.03	3	.50			8.80
1914–15	.03	3	.83			9.40
1914–15	.03	2	1			8.57
1914–15	.03	2	.33			6.12
1914–15	.03	2	.50			7.38
1914–15	.03	1	.50			6.27
POTATOES, RANCH NEAR RENO						
						Bushels
1900	5.5	13	7.43	67	8.10	363
POTATOES, NEVADA AGRICULTURAL EXPERIMENT STATION FARM, RENO						
1906–11			4.43			127
1914–17	0.01	8	1.87			255
1914–17	.01	5	2.37			176
1914–17	.01	5	3.18			223
1914–17	.01	6	1.37			266
1914–17	.01	4	1.64			159
1914–17	.01	3	2.25			153
1914–17	.01	4	.87			161
1914–17	.01	3	1.12			164
1914–17	.01	2	1.50			129
1914–17	.01	2	.50			97
1914–17	.01	2	.62			92
1914–17	.01	1	.75			59
OATS, NEVADA AGRICULTURAL EXPERIMENT STATION FARM, RENO						
1911			2.14			35
WHEAT, RANCH NEAR RENO						
1900	2	11	14.24	67	14.91	49
WHEAT, NEVADA AGRICULTURAL EXPERIMENT STATION FARM, RENO						
1914–18	0.08	2	1			26.5
1914–18	.08	2	1.25			25.7
1914–18	.08	2	1.50			25.8
1914–18	.08	2	1.25			23.5
1914–18	.08	2	1.50			29.1
1914–18	.08	2	1.75			26
1914–18	.08	2	1.50			25.1
1914–18	.08	2	1.75			25.3
1914–18	.08	2	2			26.4
ALFALFA, RANCH NEAR RENO						
	Acres					*Tons*
1900	100	8	6.55	0.67	7.22	4.5

TABLE 11.—*Use of water on crops in the Great Basin, etc.*—Continued

ALFALFA, DANGBERG RANCH

Year	Area irrigated	Number of irrigations	Quantity of water received by crop			Yield per acre
			Irrigation	Rainfall	Total	
	Acres		*Feet*	*Feet*	*Feet*	*Tons*
1907	81.3	6	5.87			6.3
1907	80.5	4	5.32			3.2
1907	102.7	3	3.40			2.9
1907	50	5	4.96			5.8

ALFALFA, NEVADA AGRICULTURAL EXPERIMENT STATION FARM, RENO

Year	Area irrigated	Number of irrigations	Irrigation	Rainfall	Total	Yield per acre
1910	1		5.08			7.5
1910	1		3.05			6.6
1910	1		2.76			5.9
1910	1		2.61			6.4
1910	1		5.78			6.6
1910	1		3.58			6
1911	1		3.64			5.2
1911	1		2.66			5.3
1911	1		2.25			4.6
1911	1		2.17			4.3
1911	1		3.87			3.3
1911	1		3.87			3.2
1915–18	.15	11	5.50			6.
1915–18	.15	7	5.40			5.81
1915–18	.15	7	6.75			6.18
1915–18	.15	7	3.50			5.59
1915–18	.15	5	3.74			5.45
1915–18	.15	5	4.50			5.43
1915–18	.15	4	1.83			4.08
1915–18	.15	4	2.66			4.42
1915–18	.15	3	2.74			4.86

CLOVER, NEVADA AGRICULTURAL EXPERIMENT STATION FARM, RENO

Year	Area irrigated	Number of irrigations	Irrigation	Rainfall	Total	Yield per acre
1914	0.06	6	3			4.45
1914	.06	3	3.50			5.52
1914	.06	5	4.75			6.97
1914	.06	4	2			3.58
1914	.06	4	3			3.51
1914	.06	3	3			4.08
1914	.06	4	2			2.71
1914	.06	4	3			3.16
1914	.06	3	3			3.38

TABLE 12.—*Use of water on crops in the Great Basin, irrigation water applied, rainfall, and crop yields in Nevada*

[Cooperative experiments, Nevada Agricultural Experiment Station]

Year	Location	Crop	Area irrigated	Number of irrigations	Quantity of water received by crop			Yield per acre
					Irrigation	Rainfall	Total	
			Acres		*Feet*	*Feet*	*Feet*	*Bushels*
1906	Mason Valley	Barley	13	4	1.04	.30	1.34	48
1906	do	do	10	4	.91	.30	1.21	48
1906	Carson Valley	do	30	3	1.36	.30	1.66	60
1906	do	do	80	3	1.44	.30	1.74	62
1906	Mason Valley	do	10	3	1.39	.30	1.69	41
1906	do	Wheat	4	2	1.31	.30	1.61	25
1906	do	do	6	4	2.81	.30	3.11	35
1906	do	do	9	4	2.45	.30	2.75	35
								Tons
1906	Lovelock Valley	do	80	2	4.53	.30	4.83	1.5

TABLE 12.—*Use of water on crops in the Great Basin, etc.*—Continued

Year	Location	Crop	Area irrigated	Number of irrigations	Quantity of water received by crop			Yield per acre
					Irrigation	Rainfall	Total	
			Acres		*Feet*	*Feet*	*Feet*	*Bushels*
1906	Lovelock Valley	Wheat	80	2	2.76	.30	3.06	33
1906	do	do	80	2	3.04	.30	3.34	33
1906	Carson Valley	do	80	3	1.07	.30	1.37	21
1906	do	do	80	3	1.25	.30	1.55	23
1906	Clover Valley	do	21	3	.93	.30	1.23	29
								Tons
1905	Lovelock Valley	Alfalfa	160	2	3.54	.30	3.84	4.5
1906	Mason Valley	do	458	2	2.64	.30	2.94	3.5
1906	Clover Valley	do	12	4	5.73	.30	6.03	2.83
1906	do	do	21	2	.77	.30	1.07	1.57
1906	Carson Valley	do	30	3	1.73	.30	2.03	4.50
1906	Nevada Agr. Exp. Sta. Truckee	do	1	7	2.75	.30	3.05	7.35
1906	do	do	1	6	3.34	.30	3.64	7.37
1906	Lovelock Valley	do	80	2	3.26	.30	3.56	6.43
1906	do	do	160	2	2.95	.30	3.25	5
1906	do	do	50	2	4.00	.30	4.30	5
1906	do	do	140	2	3.75	.30	4.05	5
1918	Reno Valley	do	.15	9	3.80	.20	4.00	5.49
1919	do	do	.15	9	5.62	.20	5.82	5.99
1919	do	do	.15	9	1.92	.20	2.12	4.45

NOTE: The soils of the river valleys of Nevada are generally composed of silt and sand with a subsoil of sand. They are spotted with clay and hardpan and irrigated very unevenly. Soil for Humboldt Basin is river bottom silt underlain with sand. Carson and Truckee Valleys have a sandy loam top soil and a sandy subsoil.

TABLE 13.—*Use of water on crops in the Great Basin, irrigation water applied, rainfall, and crop yields in Nevada*

OATS, TRUCKEE VALLEY

Year	Area irrigated	Number of irrigations	Quantity of water received by crop			Yield per acre
			Irrigation	Rainfall	Total	
	Acres		*Feet*	*Feet*	*Feet*	*Bushels*
1904	1	3	1.79	.13	1.92	48.5
1904	1	3	1.37	.13	1.50	64
1905	1	4	2.87	.18	3.05	76
1905	1	4	1.72	.18	1.90	74
1906	2	3	1.91	.30	2.21	81
1906	.20	10	2.15	.30	2.45	68
1906	.20	7	2.13	.30	2.43	122
1906	.20	4	1.32	.30	1.62	124
1906	.20	4	1.43	.30	1.73	100

BARLEY, DANGBERG RANCH, CARSON VALLEY

1908	1.38	3	2.88			61.
1908	92.	3	2.68			84.5
1908	55.	3	2.48			78.6

ALFALFA, LAMOILLE

						Tons
1917	61.	10	7.94			2.25
1917	50.08	3	3.87			.97
1917	81.8	6	3.85			2.53

TABLE 13.— *Use of water on crops in the Great Basin, etc.*—Continued

ALFALFA, DANGBERG RANCH, CARSON VALLEY

Year	Area irrigated	Number of irrigations	Quantity of water received by crop: Irrigation	Quantity of water received by crop: Rainfall	Quantity of water received by crop: Total	Yield per acre
	Acres		*Feet*	*Feet*	*Feet*	*Tons*
1918	81. 32	3	5. 87			6. 33
1918	80. 5	4	5. 32			3. 17
1918	102. 6	3	3. 40			2. 92
1918	50.	5	4. 96			5. 9
ALFALFA, LAND DEVELOPMENT RANCH NO. 3						
1919	5.	3	1. 72			4. 20
1919	7.	3	2. 15			4. 04
1920	5.	3	1. 96			4. 96
1920	7.	3	1. 92			4. 92
1921	7.	3	1. 91			4. 49
1921	5.	3	1. 87			4. 48
MEADOW, BATTLE MOUNTAIN						
1920	3. 6	5	4. 84			1. 30
1920	4. 62	5	2. 54			1. 80
1921	3. 6	2	. 62			1.
1921	4. 62	2	. 14			1. 30

NOTE.—The soils on which these experiments were carried out are of the river-laid type, a silty loam-surface layer with a sandy and gravelly subsoil. This top soil has numerous clay spots and these are rather hard to work.

TABLE 14.—*Use of water on crops in the Great Basin, irrigation water applied, rainfall, and crop yields*

[From reports of the Reclamation Service, United States Department of the Interior, Strawberry Valley, Utah]

Year and crop	Area irrigated	Number of irrigations	Quantity of water received by crop: Irrigation	Quantity of water received by crop: Rainfall	Quantity of water received by crop: Total	Yield per acre
1912	*Acres*		*Feet*	*Feet*	*Feet*	*Tons*
Alfalfa	65. 24	4	4. 40	0. 61	5. 01	2. 93
Do	15. 62	3	2. 28	. 61	2. 89	4. 61
Do	16. 16	3	2. 15	. 61	2. 76	4. 01
Do	22. 71	2	. 80	. 61	1. 41	2. 91
Do	14. 60	2	1. 00	. 61	1. 61	5. 75
						Bushels
Wheat	6. 09	3	1. 49	. 45	1. 94	32. 8
Do	5. 37	2	1. 62	. 45	2. 07	31. 6
Do	8. 11	3	2. 33	. 45	2. 78	59. 2
Do	5. 25	3	1. 35	. 45	1. 80	43
Do	2. 14	2	1. 16	. 45	1. 61	60. 7
Oats	4. 78	3	2. 59	. 45	3. 04	59. 8
Do	5. 19	3	1. 24	. 45	1. 69	75. 1
Do	2. 10	2	1. 38	. 45	1. 83	66. 7
Do	4. 71	3	1. 45	. 45	1. 90	60
Do	5. 40	2	. 99	. 45	1. 44	36
Barley	6. 31	2	1. 94	. 45	2. 39	47. 5
Do	8. 50	3	1. 68	. 45	2. 13	85
Do	6. 84	3	1. 55	. 45	2. 00	102. 7
Do	7. 08	4	2. 28	. 45	2. 73	78. 8
Do	5. 28	3	1. 06	. 45	1. 51	65. 9
						Tons
Beets	9. 94	4	1. 68	. 37	2. 05	16. 2
Do	8. 94	4	1. 93	. 37	2. 30	17. 6
Do	6. 37	4	1. 90	. 37	2. 27	14. 9
Do	6. 14	3	1. 25	. 37	1. 6[illegible]	22
Do	4. 80	8	1. 37	. 37	1. 74	18. 3

TABLE 14.—*Use of water on crops in the Great Basin, etc.*—Continued

Year and crop	Area irrigated	Number of irrigations	Quantity of water received by crop: Irrigation	Rainfall	Total	Yield per acre
1912	*Acres*		*Feet*	*Feet*	*Feet*	*Crates*
Peaches	7.95	8	1.80	.61	2.41	755
Do	3.13	8	.95	.61	1.56	671
Do	2.85	6	.99	.61	1.60	68
Do	8.74	5	.90	.61	1.51	140
1911						*Tons*
Alfalfa	67.53	15	2.23	.57	2.80	2.38
Do	16.16	12	2.25	.57	2.82	3.87
						Bushels
Wheat	11.68	4	1.10	.57	1.67	35.3
						Tons
Alfalfa	15.62	12	1.85	.57	2.42	3.54
Beets	7	8	2.84	.57	3.41	19.29
						Bushels
Wheat	3.29	4	1.78	.57	2.35	22.5
Oats	8.07	4	1.25	.57	1.82	25.5
						Tons
Beets	5.57	5	2.50	.57	3.07	11.13
						Bushels
Wheat	4.6	3	2.31	.57	2.88	39.1
Potatoes	1.02	3	1.61	.57	2.18	98
Barley	14.04	----------	1.45	.57	2.02	72
Wheat	3.03	3	1.65	.57	2.22	37.9
Do	6.32	1	.61	.57	1.18	70
Oats	3.86	2	4.02	.57	4.59	45.3
Do	5.19	4	1.20	.57	1.77	62.7
Barley	7.86	2	1.72	.57	2.29	87.9
Do	6.84	3	1.95	.57	2.52	70.3
						Tons
Beets	7	4	.66	.57	1.23	19.29
Do	6.07	5	2.32	.57	2.89	17.46
Do	5.95	3	2.46	.57	3.03	13.45
						Bushels
Do	4.23	4	2.34	.57	2.91	100
Potatoes	2.37	5	4.05	.57	4.62	168
Do	1.04	3	1.74	.57	2.31	100
Do	3.99	2	.68	.57	1.25	81

NOTE.—The soil of this area is largely sand and sandy loam on the benches derived from the weathering of the hills and from the shores of Lake Bonneville. The bottom lands contain a greater amount of clay. The lands are well cultivated and easily worked when irrigated.

TABLE 15.—*Use of water on crops in the Great Basin, irrigation water applied, rainfall, and crop yields*

[From reports of the Reclamation Service, United States Department of the Interior, Strawberry Valley, Utah]

Year and crop	Area irrigated	Number of irrigations	Monthly use of water: Apr.	May	June	July	Aug.	Sept.	Quantity of water received by crop: Irrigation	Rainfall	Total	Yield per acre
1910	*Acres*		*In.*	*In.*	*In.*	*In.*	*In.*	*In.*	*Ft.*	*Ft.*	*Ft.*	*Tons*
Alfalfa	16.16	8	-------	23.8	4.36	8.5	3.8	-------	3.37	0.76	4.13	3.87
Do	5.9	10	9.1	15.4	5.3	3.5	5.0	5.2	3.63	.76	4.39	4
Do	11	8	-------	11.6	-------	-------	-------	-------	.97	.76	1.73	5.3
Do	2.64	7	-------	16.4	-------	10.2	6.8	-------	2.80	.76	3.56	5
Do	9.47	4	-------	6.7	4.5	7.2	-------	-------	1.53	.76	2.29	4.65
Do	25.65	3	-------	5.5	5.5	2.50	2.6	-------	1.30	.76	2.06	1.75
Do	9.63	9	-------	8.1	6.3	4.7	4.5	4.2	2.31	.76	3.07	4.89
Do	7.09	12	-------	-------	-------	-------	-------	-------	5.92	.76	6.68	7.25

TABLE 15.—*Use of water on crops in the Great Basin, etc.*—Continued

Year and crop	Area irrigated	Number of irrigations	Monthly use of water						Quantity of water received by crop			Yield per acre
			Apr.	May	June	July	Aug.	Sept.	Irrigation	Rainfall	Total	
1910	*Acres*		*In.*	*In.*	*In.*	*In.*	*In.*	*In.*	*Ft.*	*Ft.*	*Ft.*	*Tons*
Sugar beets	6.68	6	------	------	7.25	12.51	15.60	7.56	3.58	.76	4.34	13.92
Do	4.11	6	------	11.3	10.6	11	------	------	2.74	.76	3.50	11.7
Do	7.9	4	------	8.9	6.4	6.9	9.4	------	2.64	.76	3.40	17.31
Do	5.6	6	------	------	5.9	11.8	12.2	6.2	3.01	.76	3.77	8.1
Do	6.49	4	------	3.4	6.2	8.1	6.6	------	2.03	.76	2.79	10.8
Do	5.35	4	------	7.4	5.4	1.91	------	------	1.23	.76	1.99	10.7
Do	9.58	6	------	.5	1.4	1.19	8.7	------	.98	.76	1.74	17.3
												Bushels
Barley	5.49	3	------	24.2	10.1	------	------	------	2.85	.76	3.61	45
Do	8.3	3	------	11.6	15.5	------	------	------	2.26	.76	3.02	63.3
Do	3.08	3	------	8.6	6.3	8.5	------	------	1.96	.76	2.72	48.7
Do	19.06	3	------	8.2	10.6	------	------	------	1.57	.76	2.33	53.1
Do	6.68	2	------	------	------	------	------	------	2.14	.76	2.90	34.99
Oats	5.43	5	------	26.9	15.23	------	------	------	3.51	.76	4.27	36.8
Do	4.06	3	------	4.67	8.72	1.01	------	------	1.20	.76	1.96	38.2
Do	3.41	4	------	8.3	8.3	18.16	------	------	2.90	.76	3.66	74.49
Orchard	7.95	4	------	1.82	4.63	2.82	------	------	.77	.76	1.53	------
Potatoes	2.3	5	------	------	------	10.3	2.9	7.5	1.73	.76	2.49	209
Do	1.1	7	------	6.15	6.3	3.3	------	2.7	1.53	.76	2.29	136.4
Wheat	11.59	4	------	24.2	10.1	6.5	------	------	3.40	.76	4.16	37.5
Do	7.15	4	------	25.1	23.8	------	------	------	4.06	.76	4.82	28
Do	4.46	4	------	6.45	10.45	5.12	------	------	1.83	.76	2.59	28.9
Do	3.78	3	------	12.3	6.0	------	------	------	1.52	.76	2.28	46.3
Do	7.3	3	------	8.8	10.9	------	------	------	1.64	.76	2.40	34.9
Do	4.85	3	------	14.1	15.3	------	------	------	2.45	.76	3.21	48.25
Do	9.76	3	------	9.1	5.4	4.8	------	------	1.61	.76	2.37	37.5
Do	------	------	------	------	------	------	------	------	4.50	.76	5.26	28.9

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